

[COMMITTEE PRINT]

FISCAL YEAR 1990 AUTHORIZATION
REQUEST AND BUDGET ESTIMATES
FOR THE
NATIONAL AERONAUTICS AND SPACE
ADMINISTRATION

R E P O R T
PREPARED BY THE
SUBCOMMITTEE ON
SPACE SCIENCE AND APPLICATIONS
TRANSMITTED TO THE
COMMITTEE ON
SCIENCE, SPACE, AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES
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*Ranking Republican Member.

LETTER OF TRANSMITTAL

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
U.S. HOUSE OF REPRESENTATIVES,
Washington, DC, June 12, 1989.

Hon. ROBERT A. ROE,
*Chairman, Committee on Science, Space, and Technology,
House of Representatives, Washington, DC.*

DEAR MR. CHAIRMAN: I am transmitting herewith an overview of the FY 1990 budget request for the National Aeronautics and Space Administration prepared by the Subcommittee on Space Science and Applications.

I believe this document will serve as an important reference and archive. Mr. Chairman, I commend this overview to you and to other Members of the Committee.

Sincerely,

BILL NELSON,
*Chairman, Subcommittee on Space
Science and Applications.*

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National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

20 MAR 1989

Honorable Bill Nelson
Chairman, Subcommittee on Space
Science and Applications
Committee on Science, Space and
Technology
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

Submitted herewith is a draft bill, "To authorize appropriations to the National Aeronautics and Space Administration for research and development; space flight, control and data communications; construction of facilities; and research and program management; and for other purposes," together with the sectional analysis thereof.

Section 4 of the Act of June 15, 1959, 73 Stat. 75 (42 U.S.C. 2460), provides that no appropriation may be made to the National Aeronautics and Space Administration unless previously authorized by legislation. It is a purpose of the enclosed bill to provide such requisite authorization in the amounts and for the purposes recommended in the President's budget plan for FY 1990. For that fiscal year the bill would authorize appropriations totaling \$13,273,995,000, to be made to the National Aeronautics and Space Administration as follows:

- (1) for "Research and development," amounts totaling \$5,751,600,000;
- (2) for "Space flight, control and data communications," \$5,139,600,000;
- (3) for "Construction of facilities," amounts totaling \$341,800,000;
- (4) for "Research and program management," \$2,032,200,000; and
- (5) for "Inspector General," \$8,795,000.

In addition, the bill would authorize appropriations of \$2,980,500,000 for FY 1991 and \$3,494,400,000 for FY 1992 for Space Station Freedom.

(IX)

The bill includes a number of other provisions including the following:

First, the language in subsection (2) of section 1(g) has been changed to that found in the "Research and program management" section of the NASA appropriations bill in order to clarify the authority and reconcile potential problems resulting from the differing formulations.

Second, there is a new section 2 which provides for multi-year authorizations for FY 1991 and FY 1992 for other than Space Station Freedom.

Third, we have included a new section 6 which was part of our FY 1989 bill but which was deleted by the Congress, which would amend the Space Act to allow NASA to withhold, from public disclosure, information which is subject to export control.

Fourth, section 7 is a new section on inventions in space which will clarify the applicability of U.S. patent laws to activities in outer space.

Fifth, we have included a new section 8, Privately Financed Facility Projects, which would amend the National Aeronautics and Space Act, as amended, to provide the Administrator with the authority to provide for commercial investment in special purpose facility projects and contingent termination liability for same.

Finally, the last section of the draft bill, section 10, provides that the bill, upon enactment, may be cited as the "National Aeronautics and Space Administration Authorization Act, 1990," rather than "1989."

As you know, NASA has, over the past several years, needed to make changes, modifications, and upgrades to many of its facilities that have been designated as National Historic Landmarks. We have been working within the Administration to develop a Programmatic Agreement which would permit us to take needed facility actions in an efficient and timely fashion while accommodating historic preservation concerns. We believe we are close to obtaining such an agreement, so the enclosed bill does not contain language addressing this issue. However, if the expected agreement is not obtained expeditiously, we plan to transmit to you an amendment to our FY 1990 Authorization Act to accommodate our concerns.

Where required by section 102(2)(c) of the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4332(2)(C)), and the implementing regulations of the Council on Environmental Quality, environmental impact statements covering NASA installations and the programs to be funded pursuant to

this bill have been or will be furnished to the House Committee on Science, Space and Technology as appropriate.

The Office of Management and Budget advises that there is no objection to the presentation of this proposal to Congress, and that its enactment would be in accordance with the program of the President.

Sincerely,

James C. Fletcher
James C. Fletcher
Administrator

2 Enclosures

cc:
Honorable F. James Sensenbrenner, Jr.

XII

A BILL

To authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SEC. 1. That there is hereby authorized to be appropriated to the National Aeronautics and Space Administration to become available October 1, 1989:

(a) For "Research and development," for the following programs:

- (1) Space Station Freedom, \$2,050,200,000; further, for the Space Station Freedom, \$2,980,500,000 to be available for obligation October 1, 1990 and to remain available until September 30, 1992; and further, for the Space Station Freedom, \$3,494,400,000 to be available for obligation on October 1, 1991 and to remain available until September 30, 1993; Provided, That for the Space Station Freedom revised baseline, the funds appropriated for U.S. program development will not exceed \$13.0 billion in fiscal year 1984 terms, adjusted for inflation and commercial participation;

- (2) Space transportation capability development,
\$639,000,000;
- (3) Physics and astronomy, \$894,500,000;
- (4) Life sciences, \$124,200,000;
- (5) Planetary exploration, \$396,900,000;
- (6) Space applications, \$579,700,000;
- (7) Technology utilization, \$22,700,000;
- (8) Commercial use of space, \$38,300,000;
- (9) Aeronautical research and technology,
\$462,800,000;
- (10) Transatmospheric research and technology,
\$127,000,000;
- (11) Space research and technology, \$338,100,000;
- (12) Safety, reliability and quality assurance,
\$23,300,000;
- (13) Tracking and data advanced systems, \$19,900,000;
- (14) University Space Science and Technology Academic
Program, \$35,000,000.

(b) For "Space flight, control and data communications,"
for the following programs:

- (1) Space shuttle production and operational
capability, \$1,305,300,000;
- (2) Space transportation operations, \$2,732,200,000;
- (3) Space and ground network, communications and
data systems, \$1,102,100,000.

(c) For "Construction of facilities," including land
acquisition, as follows:

- (1) Construction of addition for Space Systems Automated Integration and Assembly Facility, Johnson Space Center, \$10,500,000;
- (2) Construction of addition to Mission Control Center, Johnson Space Center, \$17,800,000;
- (3) Construction of addition to Simulator/Training Facility, Johnson Space Center \$3,800,000;
- (4) Modifications for Expanded Solar Simulation, Johnson Space Center, \$2,000,000;
- (5) Modifications of Process Technology Facility for Space Station, Marshall Space Flight Center, \$4,000,000;
- (6) Replace Cooling Towers, Launch Complex 39 Utility Annex, Kennedy Space Center, \$4,600,000;
- (7) Replace Launch Complex 39, Pad A Chillers and Controls, Kennedy Space Center, \$1,200,000;
- (8) Replace Roofs, Launch Complex 39, Kennedy Space Center, \$11,000,000;
- (9) Replace Vehicle Assembly Building Air Handling Units, Kennedy Space Center, \$1,800,000;
- (10) Upgrade Orbiter Modification and Refurbishment Facility to Orbiter Processing Facility #3, Kennedy Space Center, \$26,000,000;
- (11) Modification of High Pressure Industrial Water System, Stennis Space Center, \$2,000,000;
- (12) Replacement of High Pressure Gas Storage Vessels, Stennis Space Center, \$3,000,000;

- (13) Construction of natural resource protection at various locations, \$3,800,000;
- (14) Refurbish bridges, Merritt Island, Kennedy Space Center, \$4,500,000;
- (15) Rehabilitation of Spacecraft Assembly and Encapsulation Facility II, Kennedy Space Center, \$3,500,000;
- (16) Rehabilitation of Central Heating/Cooling Plant, Johnson Space Center, \$2,800,000;
- (17) Construction of Data Operations Facility, Goddard Space Flight Center, \$12,000,000;
- (18) Construction of Quality Assurance and Detector Development Laboratory, Goddard Space Flight Center, \$7,500,000;
- (19) Modernization of South Utility Systems, Jet Propulsion Laboratory, \$5,400,000;
- (20) Construction of 40 x 80 Drive Motor Roof, Ames Research Center, \$1,000,000;
- (21) Modifications to Thermo-Physics Facilities, Ames Research Center, \$4,600,000;
- (22) Modifications to 14 x 22 Subsonic Wind Tunnel, Langley Research Center, \$1,000,000;
- (23) Modifications to National Transonic Facility for Productivity, Langley Research Center, \$7,600,000;
- (24) Modifications to 20-Foot Vertical Spin Tunnel, Langley Research Center, \$1,900,000;

- (25) Rehabilitation of Central Air Systems, Lewis Research Center, \$2,400,000;
- (26) Rehabilitation of Central Refrigeration Equipment, Lewis Research Center, \$7,200,000;
- (27) Rehabilitation of 8 x 6 Supersonic and 9 x 15 Low-Speed Wind Tunnels, Lewis Research Center, \$6,800,000;
- (28) Rehabilitation of Hypersonic Tunnel, Plum Brook, \$4,100,000;
- (29) Repair and Modernization of the 12-Foot Pressure Wind Tunnel, Ames Research Center, \$27,600,000;
- (30) Construction of Automation Sciences Research Facility, Ames Research Center, \$10,600,000;
- (31) Construction of Supersonic/Hypersonic Low Disturbance Tunnel, Langley Research Center, \$6,900,000;
- (32) Modifications for Seismic Safety, Goldstone, CA, Jet Propulsion Laboratory, \$2,600,000;
- (33) Repair of facilities at various locations, not in excess of \$750,000 per project, \$28,000,000;
- (34) Rehabilitation and modification of facilities at various locations, not in excess of \$750,000 per project, \$36,000,000;
- (35) Minor construction of new facilities and additions to existing facilities at various locations, not in excess of \$500,000 per project, \$10,000,000;

- (36) Environmental compliance and restoration,
\$30,000,000;
- (37) Facility planning and design not otherwise
provided for, \$26,300,000;
- (d) For "Research and program management,"
\$2,032,200,000;
- (e) For "Inspector General," \$8,795,000;
- (f) Notwithstanding the provisions of subsection 1(i),

appropriations hereby authorized for "Research and development" and "Space flight, control and data communications" may be used (1) for any items of a capital nature (other than acquisition of land) which may be required at locations other than installations of the Administration for the performance of research and development contracts, and (2) for grants to nonprofit institutions of higher education, or to nonprofit organizations whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities; and title to such facilities shall be vested in the United States unless the Administrator determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Each such grant shall be made under such conditions as the Administrator shall determine to be required to ensure that the United States will receive therefrom benefit adequate to justify the making of that grant. None of the funds appropriated for "Research and development" and "Space flight, control and data communications" pursuant to

this Act may be used in accordance with this subsection for the construction of any major facility, the estimated cost of which, including collateral equipment, exceeds \$500,000, unless the Administrator or the Administrator's designee has notified the Committee on Science, Space and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate, of the nature, location, and estimated cost of such facility.

(g) When so specified and to the extent provided in an appropriation act, (1) any amount appropriated for "Research and development," for "Space flight, control and data communications" or for "Construction of facilities" may remain available without fiscal year limitation, and (2) contracts may be entered into under "Research and program management" for maintenance and operation of facilities, and for other services to be provided during the next fiscal year.

(h) Appropriations made pursuant to subsection 1(d) may be used, but not to exceed \$35,000, for scientific consultations or extraordinary expenses upon the approval or authority of the Administrator, and his determination shall be final and conclusive upon the accounting officers of the Government.

(i)(1) Funds appropriated pursuant to subsections 1(a), (b), and (d) may be used for the construction of new facilities and additions to, repair, rehabilitation, or modification of existing facilities, provided the cost of each such project, including collateral equipment, does not exceed \$100,000.

(2) Funds appropriated pursuant to subsection (1)(a) and (b) may be used for unforeseen programmatic facility project needs, provided the cost of each such project, including collateral equipment, does not exceed \$500,000.

(3) Funds appropriated pursuant to subsection (1)(d) may be used for repair, rehabilitation or modification of facilities controlled by the General Services Administration, provided the cost of each project, including collateral equipment, does not exceed \$500,000.

Multi-Year Authorization

SEC. 2. There is authorized to be appropriated to the National Aeronautics and Space Administration, for other than Space Station Freedom, \$11,654,700,000 for fiscal year 1991, and \$12,176,500,000 for fiscal year 1992, for the purpose of carrying out the programs authorized in section 1 of this Act.

Administrator's Reprogramming Authority

SEC. 3. Authorization is hereby granted whereby any of the amounts prescribed in paragraphs (1) through (37), inclusive, of subsection 1(c) --

(a) in the discretion of the Administrator or the Administrator's designee, may be varied upward 10 percent, or

(b) following a report by the Administrator or the Administrator's designee to the Committee on Science, Space and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of

the Senate, on the circumstances of such action, may be varied upward 25 percent, to meet unusual cost variations.

The total cost of all work authorized under paragraphs (a) and (b) shall not exceed the total of the amounts specified in section (1)(c).

Special Reprogramming Authority for
Construction of Facilities

SEC. 4. Where the Administrator determines that new developments or scientific or engineering changes in the national program of aeronautical and space activities have occurred; and that such changes require the use of additional funds for the purposes of construction, expansion, or modification of facilities at any location; and that deferral of such action until the enactment of the next authorization Act would be inconsistent with the interest of the Nation in aeronautical and space activities; the Administrator may transfer not to exceed 1/2 of 1 percent of the funds appropriated pursuant to section (1)(a) and (1)(b) to the "Construction of facilities" appropriation for such purposes. The Administrator may also use up to \$10,000,000 of the amounts authorized under section (1)(c) for such purposes. The funds so made available pursuant to this section may be expended to acquire, construct, convert, rehabilitate, or install permanent or temporary public works, including land acquisition, site reparation, appurtenances, utilities, and equipment. No such funds may be obligated until a period of 30 days has passed

after the Administrator or the Administrator's designee has transmitted to the Committee on Science, Space and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate a written report describing the nature of the construction, its cost and the reasons therefore.

Limitations on Authority

SEC. 5. Notwithstanding any other provision of this Act--

(a) no amount appropriated pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House Committee on Science, Space and Technology or the Senate Committee on Commerce, Science and Transportation,

(b) no amount appropriated pursuant to this Act may be used for any program in excess of the amount actually authorized for that particular program by subsections 1(a), 1(b) and 1(d),

(c) no amount appropriated pursuant to this Act may be used for any program which has not been presented to either such committee,

unless a period of 30 days has passed after the receipt by each such committee, of notice given by the Administrator or the Administrator's designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such proposed action.

Amendment to Space Act -- Withholding of Technical Data

SEC. 6. Section 303 of the National Aeronautics and Space Act of 1958, as amended, is amended, by adding "(a)" after "303," by removing "and" before "(B)," and by adding after "national security" the following: ", and (C) information withheld under subsection (b) below." At the end of section 303(a), add the following new section:

"(b) Notwithstanding any other provision of law, the Administrator may prescribe regulations, in consultation with concerned agencies, under which the Administration is authorized to withhold, or to require the withholding, from public disclosure any technical data in the possession of, or under the control of, the Administration, if such data may not be exported lawfully outside the United States without an authorization or license under the Export Administration Act of 1979 (50 U.S.C. App. 2401-2420) or the Arms Export Control Act (22 U.S.C. 2751 et seq.). However, technical data may not be withheld under this section if regulations promulgated under either such Act authorize the export of such data pursuant to a general, unrestricted license in such regulations."

Amendment to Space Act - Inventions in Outer Space

SEC. 7(a). Amendment. Section 305 of the National Aeronautics and Space Act of 1958, as amended, is amended by adding at the end the following new subsection:

"(m) Any invention made, used or sold in outer space on an aeronautical and space vehicle (as defined in section 103(2)) under the jurisdiction or control of the United States shall be considered to be made, used or sold within the United States for purposes of this Act, except with respect to any space vehicle or component thereof that is specifically identified and otherwise provided for by an international agreement to which the United States is a party."

(b) Effective Date.

(1) In General. Subject to subsections (2), (3) and (4) of this section, the amendments made by section (a) shall apply to all United States patents granted before, on, or after the date of the enactment of this Act, and to all applications for United States patents pending on or filed on or after such date of enactment.

(2) Amendments Not to Affect Prior Decisions. The amendments made by section (a) shall not affect any final decision made by a court or the Patent and Trademark Office before the date of the enactment of this Act with respect to a patent or an application for a patent, if no appeal from such decision is pending and the time for filing an appeal has expired.

(3) Amendments Not To Affect Certain Pending Cases. The amendments made by section (a) shall not affect the right of any party in any case pending in a court on the date of the enactment of this Act to have the party's

rights determined on the basis of the substantive law in effect before such date of enactment.

(4) Amendments To Be Prospective in Application.

Subject to subsections (2) and (3) of this section, the amendments made by section (a) shall not apply to any process, machine, article of manufacture, or composition of matter, and embodiment of which was launched prior to the effective date of this Act.

Amendment to Space Act - Privately Financed Facility Projects

SEC. 8. The National Aeronautics and Space Act of 1958, as amended, is amended by adding the following new section:

Privately Financed Facility Projects

SEC. 313. Notwithstanding the provisions of any other law, the Administration is authorized to enter into contracts, leases or agreements providing for private financing of special purpose facility projects, on government or nongovernment sites, for the exclusive or nonexclusive use of the Administration, its contractors or subcontractors: Provided, That such authorization may not be utilized unless the Administrator determines that such privately financed construction or modification is in the best interests of the Government: Provided further, That no project considered for private financing shall be initiated unless it has been submitted to the Committee on Commerce, Science and Transportation of the Senate and the Committee on Science, Space and Technology of the House of Representatives and Committees on Appropriations of the House of Representatives

and of the Senate and 30 days have passed after the Administrator's notification of a proposed action hereunder: Provided further, That if, pursuant to the above stated provisions, the Administrator authorizes privately financed construction or modification, the Administration is authorized, notwithstanding any provision of law to the contrary, to assume in the resultant contract, lease or agreement, contingent liability in excess of available appropriations relating to the Government's potential termination for its convenience of such contract, lease or agreement, if such contract, lease or agreement limits the amount of the payments that the Federal Government is allowed to make under such contract, lease or agreement to amounts to be provided in advance in appropriations Acts.

Geographical Distribution

SEC. 9. It is the sense of the Congress that it is in the national interest that consideration be given to geographical distribution of Federal research funds whenever feasible, and that the National Aeronautics and Space Administration should explore ways and means of distributing its research and development funds whenever feasible.

Title

SEC. 10. This Act may be cited as the "National Aeronautics and Space Administration Authorization Act, 1990."

SECTIONAL ANALYSIS
of a Bill

"To authorize appropriations to the National Aeronautics and Space Administration for research and development, space flight, control and data communications, construction of facilities, and research and program management, and for other purposes."

SECTION 1

Subsections (a), (b), (c), (d), and (e) would authorize to be appropriated to the National Aeronautics and Space Administration, funds, in the total amount of \$13,273,995,000, as follows: (a) for "Research and development," a total of 14 program line items aggregating the sum of \$5,751,600,000; (b) for "Space flight, control and data communications," a total of 3 line items aggregating the sum of \$5,139,600,000; (c) for "Construction of facilities," a total of 37 line items aggregating the sum of \$341,800,000; (d) for "Research and program management," \$2,032,200,000; and (e) for "Inspector General," \$8,795,000.

Subsection 1(e) is a new appropriation account for the Inspector General.

Subsection 1(f) would authorize the use of appropriations for "Research and development" and "Space flight, control and data communications" without regard to the provisions of subsection 1(i) for: (1) items of a capital nature (other than the acquisition of land) required at locations other than NASA installations for the performance of research and development contracts; and (2) grants to nonprofit institutions of higher

education, or to nonprofit organizations, whose primary purpose is the conduct of scientific research, for purchase or construction of additional research facilities. Title to such facilities shall be vested in the United States unless the Administrator determines that the national program of aeronautical and space activities will best be served by vesting title in any such grantee institution or organization. Moreover, each such grant shall be made under such conditions as the Administrator shall find necessary to ensure that the United States will receive benefit therefrom adequate to justify the making of that grant.

In either case, no funds may be used for construction of a facility in accordance with this subsection, the estimated cost of which, including collateral equipment, exceeds \$500,000, unless the Administrator notifies the specified committees of the Congress, of the nature, location, and estimated cost of such facility.

Subsection 1(g) would provide that, when so specified and to the extent provided in an appropriation act, any amount appropriated for "Research and development," "Space flight, control and data communications," or for "Construction of facilities" may remain available without fiscal year limitation. Subsection (2) states that amounts appropriated for the "Research and program management" appropriation are available for contracts for maintenance and operation of facilities and for other services for this fiscal year and for the next fiscal year. This language has been changed to that

found in the "Research and program management" section of the NASA appropriations bill in order to clarify the authority and reconcile potential problems resulting from the differing formulations.

Subsection 1(h) would authorize the use of not to exceed \$35,000 of the "Research and program management" appropriation for scientific consultation or extraordinary expenses, including representation and official entertainment expenses, upon the authority of the Administrator, whose determination shall be final and conclusive.

Subsection 1(i)(1) would provide that of the funds appropriated for "Research and development," "Space flight, control and data communications," and "Research and program management," not in excess of \$100,000 per project (including collateral equipment) may be used for construction of new facilities and additions to existing facilities, and for repair, rehabilitation, or modification of facilities.

Subsection (2) would provide that not to exceed \$500,000 per project of "Research and development" and "Space flight, control and data communications" funds may be used for facility repair or modification due to unforeseen programmatic needs.

Subsection (3) would provide that not in excess of \$500,000 per project (including collateral equipment) of funds appropriated for "Research and program management" may be used for work on facilities owned or leased by the General Services Administration.

SECTION 2 Multi-Year Authorization

Section 104 of P.L. 100-685, the National Aeronautics and Space Administration Authorization Act of 1989, provided that commencing in FY 1990 and every year thereafter, the President submits to Congress a 3-year budget request for NASA. This section authorizes appropriations for FY 1991 and FY 1992 in amounts necessary to carry out the President's FY 1990 budget for all programs other than Space Station Freedom. A three-year authorization of appropriations for Space Station Freedom is included in sec. 1(a) of this bill.

Section 3 - Administrator's Reprogramming Authority

Section 3 would authorize upward variations of the sums authorized for the "Construction of facilities" line items of 10 percent at the discretion of the Administrator or the Administrator's designee, or of 25 percent following a report by the Administrator or the Administrator's designee to the Committee on Science, Space and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate on the circumstances of such action, for the purpose of meeting unusual cost variations. However, the total cost of all work authorized under these line items may not exceed the total sum authorized for "Construction of facilities" under subsection 1(c).

SECTION 4 Special Reprogramming Authority for Construction
 of Facilities

Section 4 would provide that not more than one-half of 1 percent of the funds appropriated for "Research and development" and "Space flight, control and data communications" may be transferred to and merged with the "Construction of facilities" appropriation, to be available for the construction of facilities and land acquisition at any location if the Administrator determines that new developments or scientific or engineering changes in the national aeronautical and space program have occurred; and that such changes require the use of additional funds for the purpose of construction, expansion or modification of facilities at any location; and that deferral of such action until the next authorization act is enacted would be inconsistent with the interest of the Nation in aeronautical and space activities. Additionally, up to \$10,000,000 of "Construction of facilities" funds may be used for these purposes. However, no such funds may be obligated until 30 days have passed after the Administrator or the Administrator's designee has transmitted to the Committee on Science, Space and Technology of the House of Representatives and the Committee on Commerce, Science and Transportation of the Senate a written report containing a description of the construction, its cost, and the reasons therefore.

SECTION 5 Limitations on Authority

Section 5 would provide that, notwithstanding any other provision of this Act --

- (a) no amount appropriated pursuant to this Act may be used for any program deleted by the Congress from requests as originally made to either the House Committee on Science, Space and Technology or the Senate Committee on Commerce, Science and Transportation,
- (b) no amount appropriated pursuant to this Act may be used for any program in excess of the amount actually authorized for that particular program by subsections 1(a), 1(b) and 1(d), and
- (c) no amount appropriated pursuant to this Act may be used for any program which has not been presented to either such committee,

unless a period of 30 days has passed after the receipt by the House Committee on Science, Space and Technology and the Senate Committee on Commerce, Science, and Transportation of notice given by the Administrator or the Administrator's designee containing a full and complete statement of the action proposed to be taken and the facts and circumstances relied upon in support of such proposed action.

SECTION 6 Amendment to Space Act - Withholding of
Technical Data

This section would amend the National Aeronautics and Space Act of 1958, as amended, to provide NASA the authority to

withhold, or require the withholding, from public disclosure certain technical data that is subject to export control under the Export Administration Act of 1979 (50 U.S.C., App. 2401-2420) or the Arms Export Control Act (22 U.S.C. 2751 et seq.). The technical data subject to this amendment is only that data subject to those Acts and their implementing regulations and procedures. The amendment will provide NASA greater flexibility to manage high technology in its possession or under its control in a manner consistent with national policy regarding the export thereof. The amendment is similar to a provision amending the Freedom of Information Act (FOIA) originally contained in S. 774, the Freedom of Information Reform Act, as introduced in 1983 in the 98th Congress as well as to authority provided to the Department of Defense in section 1217 of the FY 1984 Defense Authorization Act (Pub. L. 98-84, 10 U.S.C. 140c).

As recognized by the Senate Judiciary Committee in its report (S. Rep. 98-221) accompanying S. 774, an anomaly exists between efforts to restrict the export of certain data important to the United States on the one hand, while allowing its public release under FOIA on the other. This anomaly comes about because nonproprietary technical data of the type that is subject to export control in the possession of any agency may also be subject to release under FOIA. Such release could be unrestricted and thereby obviate the requirement for an export license, or the release could even be to a foreign requester

under FOIA. The purpose of this provision is to redress that anomaly.

In removing a similar provision from S. 774 by amendment on the Senate floor in 1984, Senator Orrin Hatch (sponsor of the bill and Chairman of the Judiciary Committee's Subcommittee on the Constitution, which had jurisdiction over the bill) noted that the DoD Authorization bill had been enacted (referring to Pub. L. 98-84) to address this problem area for the DoD, and then continued:

There remain other areas with the potential of creating a problem, for instance, technical data with military or space application in the possession of NASA. In light of time constraints on this bill, it would be wisest to pursue other potential problem areas at another time. Accordingly, with a major part of the problem addressed by the proposed 10th exemption already enacted, it is the intent of this amendment to defer other concerns in this technical data area until another time. C.R., Feb. 27, 1984, S. 1797.

This amendment will resolve the matter for NASA, as suggested by Senator Hatch.

In developing its implementing regulations under the proposed amendment, NASA will coordinate its efforts with other agencies (such as the Department of Defense) who have similar authority, as well as with the agencies that administer the export control laws, in an effort to achieve standardized procedures and uniform treatment for technical data subject to the withholding authority to the maximum extent practicable. Such coordination would include identifying categories of technical data that would require continuing interagency coordination prior to release. Also, NASA will assure that its

implementing regulations exclude any technical data of another agency, a copy of which may be in the possession of NASA, consistent with present NASA policy set forth in 14 C.F.R. Part 1206. Rather, such data will be treated in accordance with whatever authority such other agency may have.

SECTION 7 Amendment to Space Act - Inventions in Outer Space

The purpose of this amendment is to provide clarity and certainty as to the applicability of U.S. patent laws to activities in outer space. This is important to commercial entities who need to know, with certainty, that their activities in space will receive the same patent protection that they would if conducted here on Earth. Removing that element of risk from the decision process of these companies will greatly increase the chances that they will proceed with their plans for activities in space.

This provision is intended to be consistent with U.S. international law obligations, including Article VIII of the Outer Space Treaty, which provides that "[a] State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body." Thus, this provision should not be interpreted to apply to a foreign-registered space object unless there is a specific agreement with the registering State in this regard.

Another aspect is that it will provide flexibility in implementing agreements with foreign partners who will be

cooperating with the United States in the development and use of the Space Station Freedom. This is possible by the exception to the strict application of U.S. patent law, for space vehicles that are specifically identified and otherwise provided for by an international agreement to which the United States is a party. Such an exception has been made, for example, regarding the applicability of 35 U.S.C. 184 (concerning filing of [patent] applications in foreign countries) in the international agreement for the Space Station Freedom.

The language of the proposed amendment is identical to that in H.R. 4316 which was passed by the House of Representatives on September 16, 1986, and H.R. 1510 which was passed by the House on October 5, 1988. Prior to such passage the bill was subject to hearings by the Subcommittee on Courts, Civil Liberties and the Administration of Justice, Committee on the Judiciary; and by the Subcommittee on Space Science and Applications, Committee on Science, Space and Technology. It has also received substantial support from private industry and the private patent bar.

SECTION 8 Privately Financed Facility Projects

The National Aeronautics and Space Administration (NASA) recognizes the importance of commercial investment and involvement in the construction and modification of facilities utilized in the United States civil space program. NASA, however, currently lacks the legal authority necessary to fully utilize these important tools. This amendment to the FY 1990 NASA Authorization Bill gives NASA that authority.

This amendment would amend the National Aeronautics and Space Act of 1958 (P.L. 85-568), as amended, providing permanent legislation which would allow NASA, notwithstanding any law to the contrary, to enter into contracts, leases or agreements providing for private financing of such special purpose facility projects, on government or on nongovernment sites, and for the exclusive or nonexclusive use of NASA, its contractors, or subcontractors whenever the Administrator of NASA determines that it is in the best interest of the Government to do so. The amendment would preclude the initiation of such privately financed facility projects until 30 calendar days had passed following the Administrator's notification to the authorizing and appropriation committees of proposed actions.

NASA also currently lacks legal authority to assume, in resultant contracts, leases or agreements, contingent termination liability in excess of available appropriations. Since it is highly improbable that private parties will provide financing for facility projects unless their investments in the projects are protected through Government assumption of contingent liability in the event they are terminated by the Government, it is necessary to the success of these privately financed facility projects that NASA be provided that authority. This amendment gives NASA the necessary authority.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1990 BUDGET ESTIMATES

GENERAL STATEMENT

The National Aeronautics and Space Administration conducts space and aeronautical research, development and flight activities for peaceful purposes designed to maintain United States preeminence in aeronautics and space. The National Space Policy emphasizes continuing the national commitment to a permanently manned Space Station, pursuing vigorous programs in space science and space technology, creating opportunities for United States commerce in space and the long-range goal of expanding human presence and activity beyond Earth orbit into the solar system. The priority given to the National Space Policy is clearly demonstrated by the increased funding recommended for civil space programs in this budget.

The NASA FY 1990 budget request of \$13.3 billion supports the National Space Policy by providing the resources necessary to support a vigorous national program ensuring leadership in areas critical to space as well as continued preeminence in aeronautics. This budget concentrates on:

- Providing for safe and effective Space Transportation Operations and assured access to space using both the Space Shuttle and Expendable Launch Vehicles;
- Moving forward in the establishment of a permanently occupied Space Station in Earth orbit;
- Continuing an effective Space Science and Applications program to expand our knowledge of the Earth, its environment, the solar system and the universe and human habitation of space;
- Strengthening the basic capabilities of NASA and developing the technology base for future orbital operations and exploration of space;
- Providing the facilities, technology and expertise necessary for superiority in civil and military aviation;
- Providing opportunities for commercialization of space through private sector participation including investment in major civil space program activities, and for international cooperation in space.

The program elements outlined in this budget will provide a strengthened base for assuring and continuing the United States' role as leader in space and aeronautical research and development. Specific major areas of emphasis are:

Space Transportation

The Space Shuttle has safely returned to flight and the primary program objective of the current budget is completion of this recovery effort and conducting the planned flights in a safe and reliable manner, and to provide for the necessary capabilities to fly the payloads scheduled for launch. The budget provides for five flights in FY 1989 and nine flights in FY 1990, ultimately leading to a capability of fourteen flights per year. Design and development activities will continue in FY 1990 to complete those activities associated with the redesigned solid rocket motor and to continue efforts to expand the operating margins in the main engines and development of the Advanced Solid Rocket Motor (ASRM). The ASRM is intended to improve the safety, reliability and performance of the Shuttle fleet. Development of improvements to the Shuttle for extending the stay time in orbit will be continued with NASA seeking private sector investment for elements of this program.

In other aspects of Space Transportation, the FY 1990 budget includes funding for procurement of Upper Stages, the preparation of the Spacelab to resume flights in 1990, continued development of the Orbital Maneuvering Vehicle, the Tethered Satellite System and the Advanced Launch System. Development of a docking module for use between the Shuttle and Space Station or other spacecraft requiring this capability will be initiated, with private sector investment being pursued for the docking module development. Funding for expendable launch vehicle services for selected Space Science and Applications missions implementing NASA's mixed fleet plan is included, as well as for other activities necessary to provide the basis for a robust space transportation system.

Space Station

The Space Station Freedom program is the centerpiece of the Nation's space program of the 1990s. The Space Station will provide our first opportunity to gain direct experience in long term human operations in space, and knowledge essential to future space exploration. It will enhance the U.S. space science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an avenue of cooperation with our allies, demonstrating the peaceful use of space for the benefit of all. The Space Station Freedom has seen significant progress during the past year. The development plan and configuration are firm and the development contractors are making substantial progress. Negotiations with the international partners for the development phase of the program were completed in the fall of 1988. Agreements have been signed with the Canadian government and member countries of ESA, with a formal signing of the memorandum of understanding with the Japanese government expected in the spring of 1989.

In addition to supporting the request for nearly \$2.1 billion of new obligational authority in FY 1990, the Administration is proposing legislation for a three year Congressional commitment for advanced authorization and appropriations of \$8.5 billion including the FY 1990 amount. The Administration is also proposing legislation to establish a total development program cost ceiling of \$13.0 billion (in 1984

dollars, adjusted for inflation and commercialization). In addition, consistent with the Administration's policy, NASA will be actively pursuing approaches to encourage private sector participation, including investment, in the Flight Telerobotic Servicer capability, the Space Station docking system and future requirements for the Space Station, including those under study, e.g., Solar Dynamic Power and equipment to utilize the Space Station. Funding is included to initiate the development of a radar to track and monitor small size orbital debris.

Space Science and Applications

The FY 1990 budget provides for a carefully coordinated and logically phased set of research and development activities to:

- Advance our scientific knowledge of Earth and of the forces and systems that shape our planet;
- Explore the solar system using automated spacecraft in conjunction with ground-based observations and research;
- Expand our comprehension of the universe beyond the solar system using the full range of capabilities from Explorer spacecraft to the orbiting Great Observatories;
- Increase our knowledge in the Life Sciences on key issues ranging from human performance and habitation in space to the basic life processes and the potential of life elsewhere in the universe; and
- Understand and develop the potential benefits of the microgravity environment in materials sciences and other applications.

The Space Science and Applications program is ready to take full advantage of the resumption of access to space through the Shuttle and Expendable Launch Vehicles services. Current planning supports launch of Magellan and Galileo in 1989, launch of the Hubble Space Telescope in late 1989, and launch of Ulysses and the Gamma Ray Observatory in 1990. The Cosmic Background Explorer and Roentgen Satellite are scheduled to be launched on Delta expendable launch vehicles in 1989 and 1990, respectively. Development continues on the Gamma Ray Observatory, the Upper Atmosphere Research Satellite, the Mars Observer, the Ocean Topography Experiment, the Global Geospace Science Mission, the Collaborative Solar Terrestrial Research program and mirror and science instrument development in preparation for the start of the Advanced X-ray Astrophysics Facility spacecraft in 1992. Development and integration activity continues in preparation for future Spacelab missions and for secondary payloads to conduct microgravity and life sciences experiments. Funds are also included to initiate design and development of the Comet Rendezvous/Asteroid Fly-by/Cassini missions. These missions will send one spacecraft to study at close range a comet and its

total environs and a second spacecraft to study the planet Saturn, its atmosphere, rings and its moon, Titan. This project will include participation by the Federal Republic of Germany and the European Space Agency. Funding is also included to continue data processing and investigations from the Voyager 1 and 2 spacecrafts as they leave the solar system. These spacecraft will gather data on the interstellar fields and particles unaffected by the solar plasma.

Commercial Activities

The FY 1990 budget supports development of the private sector innovative excellence and confirms NASA's commitment to encouraging a healthy and expansive commercial space industry. Funding is included for the integration of a commercially developed space facility into the Shuttle and, in future years, lease of space for government payloads. NASA plans to procure launch services from the private sector for a number of important scientific satellite missions. Commercially-developed upper stages are being used where appropriate for planned missions. Commercial microgravity experiments to be conducted as secondary payloads are manifested on planned Shuttle missions. NASA will actively pursue approaches to encourage the private sector to invest in elements of several NASA programs, including the Flight Telerobotic System, the Extended Duration Orbiter, and the Space Station Docking System. There are several initiatives underway to involve the private sector in developing the infrastructure necessary for research and manufacturing in space, and NASA strongly supports these initiatives. An agreement was concluded in FY 1988 to provide launch services on a deferred payment basis for the commercially developed "Spacehab" microgravity facility which will fly on the Shuttle, and an agreement has been signed with the University Corporation for Atmospheric Research for use of the Shuttle external tanks.

Space Research and Technology

This program develops the technology base on which our current and future capabilities in space depend. The Civil Space Technology Initiative started in FY 1988, and the Pathfinder program started in FY 1989 will develop technology requirements for future missions and significantly enhance current capabilities to access and operate in space at greatly reduced overall mission costs. The in-space flight experiments technology program is also included as a new initiative. This program provides for the development and/or demonstration of critical technologies which require the actual space environment and will provide precursor information for the development of advanced technology experiments to be flown on the Space Station.

Aeronautics Research and Technology

The goal of the Aeronautics program is to provide a technology base for the continued U.S. preeminence in the field of aeronautics. This is accomplished by maintaining a broad based research and technology program utilizing advanced facilities, laboratories, computers and technical staff, with extensive involvement of the U.S. university and industrial sectors.

The FY 1990 Research and Technology program is committed to developing the technology to improve our nation's competitiveness and product superiority in the international marketplace, enhancing the safety of aviation, and increasing U.S. leadership in aviation for national security. A funding augmentation is included for high-speed research which will focus on resolution of the critical environmental issues concerning ozone depletion, airport noise and sonic booms to make informed decisions on high-speed aircraft development in the future.

Transatmospheric Research and Technology

The NASA efforts in this area are aimed at accelerating the development of critical technologies intended to enable a potential new class of vehicles in the future capable of flight to orbit and/or hypersonic cruise. Work will continue in the development of technology for hypersonic and transatmospheric vehicles for the National Aerospace Plane program with emphasis on lightweight thermal structures and supersonic and hypersonic propulsion. Potential future applications include vehicles to transport people to orbit, hypersonic transport between points on Earth and military defense.

Space and Ground Network, Communications and Data Systems

The FY 1990 budget provides vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. Work will continue on the replacement Tracking and Data Relay Satellite (TDRS) spacecraft and on the Second TDRS Ground Terminal both of which are vitally needed to insure continuity of tracking support.

University Space Science and Technology Academic Program

This new budget line item provides for continuation of agency-wide university and minority university programs previously budgeted in other NASA programs. FY 1990 funding will support graduate and undergraduate student fellowships, faculty fellowships, the historically black colleges and university research program, other minority universities, and the Space Grant College and Fellowship program.

Work Force Capability

The NASA institutional capability is the underpinning for the successful accomplishment of the nation's aeronautics and space programs. The FY 1990 budget provides funding for an increase in civil service people who are urgently required to meet the staffing levels associated with Space Station and to strengthen NASA's science and engineering core workforce. Hands on work in-house gives NASA the knowledge to manage the 85 percent of NASA's work that is contracted to private industry, and the ability to respond quickly to management or technical problems as they occur.

Construction of Facilities

The FY 1990 budget provides funding for construction of new facilities as well as the maintenance and repair of the NASA physical plant. The principal projects planned for FY 1990 include facilities needed for space flight, Space Station, space technology, and space science and applications activities, continuation of the multiyear effort to restore and modernize NASA's aeronautical research and development facilities and support of minor projects and future planning activities. Private sector financing will be sought for the Neutral Buoyancy Laboratory at the Johnson Space Center, the Space Station processing facility at the Kennedy Space Center, the Advanced Solid Rocket production and test facility, and the Observational Instruments Laboratory at the Jet Propulsion Laboratory.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FY 1990 BUDGET SUMMARY (Millions of Dollars)

	Budget Plan	
	1988	1990
RESEARCH AND DEVELOPMENT		
Space station	3,254.9	5,751.6
Space transportation capability development	392.3	2,050.2
Space science and applications	593.4	639.0
Technology utilization	1,581.8	1,995.3
Commercial use of space	19.0	22.7
Aeronautical research and technology	29.7	38.3
Transatmospheric research and technology	332.9	462.8
Space research and technology	52.5	127.0
Safety, reliability and quality assurance	221.3	338.1
University space science and technology academic program	14.1	23.3
Tracking and data advanced systems	(21.6)	35.0
	17.9	19.9
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS		
Shuttle production and operational capability	3,805.7	5,139.6
Space transportation operations	1,092.7	1,305.3
Space and ground networks, communications and data systems	1,833.6	2,732.2
	879.4	1,102.1
CONSTRUCTION OF FACILITIES		
	178.3	341.8
RESEARCH AND PROGRAM MANAGEMENT		
	1,762.2	2,032.2
INSPECTOR GENERAL		
	(7.1)	8.8
TOTAL BUDGET SUMMARY		
	9,001.1	13,274.0
OUTLAYS		
	9,091.6	12,706.8

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FISCAL YEAR 1990 ESTIMATES
SUMMARY RECONCILIATION OF APPROPRIATIONS TO BUDGET PLANS
(Millions of Dollars)

	TOTAL	Research and Development	SFCBDC	C of F	NSM	Inspector General
FISCAL YEAR 1989						
Appropriation P. L. 100-202	8,856.5	3,274.2	3,908.3	170.3	1,495.7	(7.1)
Reappropriation P. L. 100-202	100.0	100.0	---	---	---	---
Reversion P. L. 100-406	-25.0	-25.0	---	---	---	---
Transfer between accounts	0.0	-159.4	-102.6	---	262.0	---
Transfer between Fed Agencies	70.8	65.1	---	---	4.9	---
Lapse	-0.4	---	---	---	-0.4	---
Total Budget Plan	9,001.1	3,254.9	3,805.7	170.3	1,762.2	0.0
FISCAL YEAR 1990						
Appropriation P. L. 100-406	10,701.0	4,191.7	4,304.2	290.1	1,855.0	(0.6)
Transfer between accounts	0.0	---	---	-30.0	30.0	---
Transfer between Fed Agencies	106.5	74.9	100.0	15.0	6.6	---
Total Budget Plan	10,807.5	4,266.6	4,404.2	275.1	1,891.6	(0.6)
FISCAL YEAR 1990						
Appropriation Request/Budget Plan	19,274.0	5,751.6	5,120.6	301.0	2,032.2	0.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

FISCAL YEAR 1960 ESTIMATES

SUMMARY OF BUDGET PLANS BY INSTALLATION BY APPROPRIATION

(Thousands of Dollars)

	Total		Space Flight Control and Data Communications		Research and Development		Construction of Facilities		Research and Program Management	
	1959	1960	1959	1960	1959	1960	1959	1960	1959	1960
Johnson Space Center	1,328,260	1,489,845	2,356,806	987,750	1,515,000	1,110,400	327,432	549,945	1,147,448	0
Kennedy Space Center	1,074,320	1,196,301	1,200,422	719,700	601,400	678,000	96,016	112,401	185,234	0
Marshall Space Flight Center	2,282,240	2,491,216	3,853,254	1,261,200	1,576,400	1,709,600	744,414	774,551	879,460	0
Stennis Space Center	66,717	76,927	86,042	19,100	26,000	16,000	16,179	16,070	14,654	0
Goddard Space Flight Center	1,232,856	1,391,602	2,044,732	646,325	559,400	716,000	380,842	744,940	984,632	0
Jet Propulsion Laboratory	616,463	689,450	734,400	131,515	126,400	136,400	486,214	557,550	582,339	0
Ames Research Center	476,297	511,444	592,407	15,400	17,200	20,300	281,162	282,424	332,711	0
Langley Research Center	382,376	455,445	504,165	100	4,000	6,000	197,149	246,734	272,495	0
Lewis Research Center	402,856	436,542	621,372	2,700	26,000	32,300	254,732	267,232	325,417	0
Headquarters	676,614	1,162,610	1,356,466	282,000	315,000	380,000	374,547	535,344	769,977	0
Distributed Construction of Facilities:										
Various Locations	0,637	52,400	19,225	0	0	0	0	0	0	0
Facility Planning and Design	16,000	26,000	26,500	0	0	0	0	0	0	0
Total Budget Plan	9,491,832	10,497,540	13,185,280	3,693,700	4,446,200	5,110,600	2,316,660	6,160,660	5,791,660	176,272
Transfer Budget	(7,000)	(6,000)	6,793							
Total Agency	9,484,832	10,491,540	13,192,073							

DISTRIBUTION OF PERMANENT CIVIL SERVICE WORKYEARS BY INSTALLATION

	1989			1990	
	1988 ACTUAL	BUDGET ESTIMATE	CURRENT ESTIMATE	BUDGET ESTIMATE	
JOHNSON SPACE CENTER.....	3,302	3,460	3,463	3,605	
KENNEDY SPACE CENTER.....	2,167	2,324	2,331	2,357	
MARSHALL SPACE FLIGHT CENTER.	3,351	3,461	3,481	3,607	
STENNIS SPACE CENTER.....	140	159	166	174	
GODDARD SPACE FLIGHT CENTER..	3,586	3,584	3,618	3,651	
AMES RESEARCH CENTER.....	2,065	2,068	2,097	2,153	
LANGLEY RESEARCH CENTER.....	2,811	2,812	2,835	2,888	
LEWIS RESEARCH CENTER.....	2,640	2,646	2,664	2,743	
HEADQUARTERS.....	1,320	1,416	1,403	1,431	
INSPECTOR GENERAL.....	119	151	136	0	
SUBTOTAL, FULL-TIME PERMANENT WORKYEARS	21,500	22,081	22,194	22,609	
OTHER THAN FULL-TIME PERMANENT WORKYEARS	682	726	738	743	
SUBTOTAL, CEILING CONTROLLED FTE	22,182	22,807	22,932	23,352	
SPACE STATION (RESTON, VA)	144	143	218	345	
TOTAL, CEILING CONTROLLED FTE	22,326	22,950	23,150	23,700	
	=====	=====	=====	=====	

NOTE: THE INSPECTOR GENERAL'S OFFICE WAS GRANTED ITS OWN APPROPRIATION, THUS IG WORKYEARS (146) WILL NOT APPEAR IN FY 1990 TOTALS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1990 MULTI-YEAR BUDGET ESTIMATES
(IN MILLIONS OF REAL YEAR DOLLARS)

As directed by the NASA FY 1989 Authorization Law (P.L. 100-685), the following table contains the budget estimates for FY 1990, 1991 and 1992 to implement the President's FY 1990 program:

	1988 ACTUAL	1989 CURRENT ACTUAL	1990 BUDGET ESTIMATE	1991 ESTIMATE	1992 ESTIMATE
RESEARCH AND DEVELOPMENT	3235	4267	5752	7013	7682
SPACE STATION	392	900	2050	2981	3494
SPACE TRANSPORTATION CAPABILITY DEV	593	681	639	693	649
PHYSICS & ASTRONOMY	614	734	895	988	1112
LIFE SCIENCES	72	78	124	154	151
PLANETARY EXPLORATION	328	417	397	470	591
SPACE APPLICATIONS	568	601	580	518	500
SPACE SCIENCE AND APPLICATIONS	1582	1830	1995	2130	2355
TECHNOLOGY UTILIZATION	19	17	23	23	21
COMMERCIAL USE OF SPACE	30	28	38	53	52
COMMERCIAL PROGRAMS	42	45	61	76	73
AERONAUTICAL RESEARCH & TECHNOLOGY	333	404	463	502	531
TRANSATMOSPHERIC RESEARCH & TECH	53	70	127	119	72
SPACE RESEARCH & TECHNOLOGY	221	296	338	430	420
SAFETY, RELIABILITY AND QUALITY ASSURANCE	14	22	23	24	24
UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAM	(22)	(22)	35	38	41
TRACKING AND DATA ADVANCED SYSTEMS	16	12	20	21	22
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	3806	4464	5140	5171	5516
SHUTTLE PROD & OPERATIONAL CAP	1093	1128	1305	1303	1368
SPACE TRANSPORTATION OPERATIONS	1806	2305	2563	2495	2678
EXPENDABLE LAUNCH VEHICLES	28	86	170	214	242
SPACE & GROUND NETWORK, COMM AND DATA SYSTEMS	879	945	1102	1159	1228
CONSTRUCTION OF FACILITIES	178	275	342	350	350
RESEARCH AND PROGRAM MANAGEMENT	1762	1892	2032	2092	2114
INSPECTOR GENERAL	(7)	(9)	2	2	2
TOTAL NASA	9001	10998	13274	14635	15671

XLVIII

NASA FY 1990 SPREAD SHEET

	<u>FY 1989</u> <u>Approp.</u>	<u>FY 1990</u> <u>Request</u>
<u>RESEARCH AND DEVELOPMENT</u>	<u>4,266.6</u>	<u>5,751.6</u>
Space Station	900.0	2,050.2
Space Trans. Cap. Dev.	681.0	639.0
Physics & Astronomy	734.1	894.5
Life Sciences	78.1	124.2
Planetary Exploration	416.6	396.9
Space Applications	601.4	579.7
Technology Utilization	16.5	22.7
Commercial Use of Space	28.2	38.3
Aeronautical Res. & Tech.	404.2	462.8
Space Research and Technology	295.9	338.1
Transatmospheric Res. & Tech.	69.4	127.0
Safety, Reliability & Qual. Assur.	22.4	23.3
University Space Science & Tech.	(22.3)	35.0
Tracking & Data Adv. Sys.	18.8	19.9
<u>SPACE FLIGHT, CONTROL & DATA COM.</u>	<u>4,464.2</u>	<u>5,139.6</u>
Shuttle Prod. & Capability Dev.	1,128.2	1,305.3
Space Shuttle Operations	2,305.2	2,562.7
Expendable Launch Vehicles	85.5	169.5
Space & Ground Net./Com./Data Sys.	945.3	1,102.1
<u>CONSTRUCTION OF FACILITIES</u>	<u>275.1</u>	<u>341.8</u>
<u>RESEARCH & PROGRAM MGT.</u>	<u>1,891.6</u>	<u>2,032.2</u>
<u>INSPECTOR GENERAL</u>	<u>(8.6)</u>	<u>8.8</u>
TOTAL NASA	10,897.5	13,274.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

RESEARCH AND DEVELOPMENT

FISCAL YEAR 1990 REQUESTS

[Dollars in millions]

	1989 current estimate	1990 budget request
Space station	\$900.0	\$2,050.2
Space transportation capability development.....	681.0	639.0
Space science and applications	1,830.2	1,995.3
Physics and astronomy	734.1	894.5
Life sciences.....	78.1	124.2
Planetary exploration.....	416.6	396.9
Earth sciences	413.7	434.3
Materials processing	75.6	92.7
Communications	92.2	18.6
Information systems.....	19.9	34.1
Commercial programs	44.7	61.0
Technology utilization	16.5	22.7
Commercial use of space	28.2	38.3
Aeronautics and space technology	769.5	927.9
Aeronautical research and technology	404.2	462.8
Transatmospheric research and technology	69.4	127.0
Space research and technology	295.9	338.1
Safety, reliability and quality assurance.....	22.4	23.3
University space science and technology academic programs	(22.3)	35.0
Tracking and data advanced systems.....	18.8	19.9
Total	4,266.6	5,751.6

SPACE STATION

FY 1990 BUDGET REQUEST \$2,050,200,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Development.....	\$842,000,000	\$1,970,200,000
Flight telerobotics servicer.....	46,000,000	15,000,000
Operations		25,000,000
Transition definition.....	12,000,000	25,000,000
Orbital debris radar		15,000,000
Total	900,000,000	2,050,200

Development of the United States (U.S.) permanently manned Space Station, as directed by President Reagan, will add new momentum to the civil space program and is essential to preserving U.S. preeminence in science, technology and manned space flight. The Space Station Freedom (SSF) program gives us our first opportunity to gain direct experienced in long term human operations in space, and knowledge essential to future space exploration. The Space Station will uniquely enhance the U.S. space science programs, further the commercial utilization of space, and stimulate the development and application of advanced technologies of national importance. It is also an avenue of cooperation with our allies, demonstrating the peaceful use of space for the benefit of all.

The SSF will be unique because it will provide the U.S. with a permanently manned presence in space. It will be versatile because its capabilities will be remarkably diverse. This diversity is reflected in the Space Station's design, which features pressurized laboratories, accommodations for attached payloads, and free-flying unmanned platforms. This new national laboratory, a research center in space, will stimulate new technologies, enhance industrial competitiveness, further commercial space enterprises, and add greatly to our storehouse of scientific knowledge. Perhaps the most significant feature of the Space Station, essential to its utility for science, commerce, and technology, is the continuing presence of its crews. Men and women will be aboard the Space Station base full-time. The potential of humans—their creativity—is unique and essential. The Space Station will be designed to exploit the human capabilities. The Space Station's microgravity environment, high levels of power, and extended time in orbit, will enable scientists to make new discoveries in materials research and life sciences. The Space Station's substantive research capabilities include far more than its pressurized volume. Its free-flying platforms will enable truly synergistic studies of the Earth's atmosphere, land masses, and

oceans—referred to as Earth system science. These activities will complement the proposed mission to Planet Earth which will help us to understand our environment and aid us in learning to conserve its precious resources. Moreover, the Space Station's external structure is designed to be a stable platform that will be available for mounting a number of specialized instruments and telescopes. Scientific instruments, whether in a laboratory or on a boom, require maintenance, upgrading, repair and replacement. The Space Station will accommodate these servicing function. The SSF will be designed to evolve, to be capable of growth in its capabilities, so that future needs and challenges can be met.

The SSF will be a multipurpose, international facility. In 1984, President Reagan invited the full participation of other nations. During the ensuing definition phase, Canada, member states of the European Space Agency (ESA), and Japan worked closely with the U.S. to define their participation. These parallel definition and preliminary design studies have resulted in the identification of the Space Station elements to be developed by our partners. Negotiations with these international partners for the development phase of the program were completed in the fall of 1988. Agreements have been signed with the Canadian government for the development of a mobile servicing system and with the member countries of ESA for the inclusion of a pressurized attached module, a man-tended free flyer, and a polar platform. Negotiations with the Japanese government for the development of an attached laboratory module have been completed with formal signing expected in the spring of 1989.

The basic configuration of the SSF and the supporting elements has been arrived at as a result of a lengthy iterative three-year process involving NASA centers, U.S. industry, our international partners, and the national and international science communities. The revised baseline is comprised of a single horizontal boom structure with 75KW of photovoltaic power, the U.S. laboratory and habitability modules, two international laboratory modules (one European and one Japanese), and a Canadian mobile servicing capability. These elements comprise the manned base, and provide internal and external accommodations for the attachment of science and application payloads. There are also two science and applications platforms, one U.S. and one European, to be launched into polar orbit. A man-tended free-flyer is also under consideration by ESA as a co-orbiting platform with the manned base. The launch of the first element is planned for March 1995.

In addition to the development of the manned base and U.S. polar platform, the Space Station program will include development of a Flight Telerobotics Servicer (FTS). The FTS will be a highly automated telerobotic device capable of precise manipulations in space. The FTS on board the Space Station will increase safety and productivity by reducing Extra Vehicular Activity (EVA) time, allowing the use of robotics for hazardous tasks, and freeing crew members for scientific tasks. The FTS will play a key role in the development of automation and robotics (A&R) technologies which will be of benefit not only in space but in ground based applications such as manufacturing. Private sector investment in the FTS is being proposed in order to strengthen private sector in-

volvement in the Space Station program, while at the same time offsetting the need for full Federal funding for development of the FTS.

As noted above, a key design objective of the Space Station is to enable hardware and software to evolve in response to increased user demands and the need for augmented operational capabilities. The Transition Definition activities will provide for systems studies to define options for evolution of the Space Station consistent with future agency missions and for technology development, primarily in automation and robotics, that will enhance the Space Station productivity and private investment in the future Space Station requirements, including those under study. These activities are essential for the long-term cost-effective utilization of the Space Station.

Funding for the development and construction of an orbital debris radar is also provided in this budget request. Monitoring, characterization and assessment of small debris is critical for determining any protective measures needed for incorporation in the Station design. A radar operational in the fourth quarter of CY 1991 is necessary to support the Station critical design reviews in 1992. Studies and preliminary definition for the radar is being provided by the Office of Space Flight.

The Space Station operations encompass all activities required to maintain the Space Station and platforms for their planned lifetime. This includes logistics support, crew training, mission operations, engineering support, launch processing, and user training and operations. Funding for the initial stages of this effort is included in the FY 1990 budget request.

In an ongoing effort to ensure development of the most productive and cost-effective station possible, the SSF program has completed a series of intensive reviews regarding program content and rationale, flight system configuration, and overall reasonableness of the total cost estimate. The most comprehensive review as conducted at the request of President Reagan by the National Research Council's (NRC) Committee on Space Station. The NRC's task was to assess NASA's cost estimates for the Space Station program and to examine the Space Station mission requirements and alternative configurations. This Committee issued its final report on September 10, 1987. The Committee found that the revised baseline configuration was "a satisfactory starting point for the Space Station . . . and reflects thoughtful compromises among the priorities and sometimes conflicting requirements of its early scientific and engineering users." The Committee also stressed the importance of having a robust space transportation system, development of an adequate ground test program and backup hardware policy, strengthened Space Station program management, and emphasis on the operational aspects of the program. These recommendations received special attention during the Program Requirements Review (PRR).

During 1988, the SSF program undertook a very thorough and extensive analysis of the program requirements. The purpose of this PRR was to evaluate requirements and to ensure horizontal and vertical consistency in the requirements and in the program documentation. Over six thousand review item discrepancies were surfaced and are being resolved. All of the Space Station program

elements, systems, and participants were included. This review reinforced the basic soundness of the current program design.

In FY 1988, the Congress directed a significant reduction in the funding appropriated for the Space Station program in FY 1988. The amount requested by NASA for FY 1988, \$767 million, was reduced to \$425 million including \$100 million transferred from 1987 replacement orbiter production funds. After adjustments for a directed realignment between the research and development appropriation and the research and program management appropriation, the revised plan for FY 1988 was \$392.3 million. In FY 1989, NASA requested \$967.4 million for the Space Station. As a result of Congressional appropriation action, the Space Station amount was reduced to \$900 million. Congressional action further constrained the Space Station program in FY 1989, by allowing for availability of \$385 million in new obligational authority until May 15, 1989. The remaining \$515 million will become available after May 15, assuming no objection by the President is made after February 1, 1989.

At the request of Congress, NASA prepared and delivered to Congress, in early 1988, a study which assessed the impact of the reduced FY 1988 and FY 1989 funding. At the time of this study, the FY 1989 funding level was assumed to be the \$967.4 million which NASA had requested for Space Station. Prior to the reductions in FY 1988 and FY 1989, NASA had planned for a First Element Launch (FEL) in the first quarter of CY 1994. This date was predicated upon a funding level of \$767 million in FY 1988 and \$1.8 billion in FY 1989. Evaluating the results of the reductions to \$425 million and \$967.4 million respectively, it was determined that this schedule could not be met and that FEL would need to slip by one year to the first quarter of CY 1995. At the same time, NASA agreed to provide for an early manned capability on orbit by accelerating the launch of the laboratory module from 1996 to the fourth quarter of CY 1995. The above schedule assumes receipt of the requested funding of \$2,050.2 million for FY 1990.

This budget requests appropriations for the Space Station of \$2,050.2 million for FY 1990, and \$2,980.5 million for FY 1991, and the authorization and appropriation of \$3,494.4 million for FY 1992. During the FY 1989 budget process, the Administration requested similar legislation for a Congressional commitment to a three year authorization and appropriation of Space Station funds for FY 1989, FY 1990 and FY 1991 in an amount totalling \$6,010.1 million. This request was included in the NASA 1989 authorization bill passed by Congress and signed by the President. Continuation of these measures on the part of Congress and the Administration will provide increased program stability while maintaining cost control discipline for both development and operations. In addition, the Administration plans to request legislation to establish a total development program cost ceiling of \$13 billion, in FY 1984 constant dollars adjusted for inflation and private investment. These commitments will help assure international participants of the U.S. commitments to SSF development and recognizes the importance of their cooperation on the Space Station program.

In support of the President's policy on the commercial use of space, NASA, in consultation with the OMB, recently released drafts of revised guidelines, policy, procedures and criteria for in-

dustry comment. These guidelines on the commercialization of the Space Station will serve to reaffirm, clarify and strengthen its commitment to private sector investment and involvement in the Space Station program. NASA will give positive consideration to proposals to accelerate private sector investment in Space Station development and operations in the form of either goods or services which have not yet been contracted. Further, NASA will actively pursue approaches to encourage the private sector to invest in the FTS the Space Station docking system and future requirements for the Space Station, including those under study, e.g., solar dynamics power and equipment to utilize the Space Station.

DEVELOPMENT

	1989 current estimate	1990 budget request
Management and integration	\$187,700,000	\$230,200,000
Pressurized modules	155,500,000	366,000,000
Assembly hardware/subsystems	263,200,000	762,000,000
Platforms and servicing	51,200,000	130,000,000
Power system	120,000,000	298,000,000
Operations/utilization capability development	64,400,000	184,000,000
Total	842,000,000	1,970,000,000

As a research facility in space, the SSF will provide opportunities for significant advances in science, technology and commerce. It must be flexible yet durable in its capabilities, as the Station will be on orbit for many years. It must be operationally affordable for its success will be measured by its operational utility. The objectives of the program are: (1) to establish a permanently manned research facility in low-Earth orbit in the mid-1990's with the capability to evolve to meet future potential requirements; (2) to enhance mankind's evolving ability to live and work safely in space; (3) to stimulate technologies of national importance (especially automation and robotics) by using them to provide needed capabilities; (4) to provide cost-effective operation and utilization of continually improving facilities for scientific, technological, and operational activities enabled or enhanced by the presence of man in space; (5) to foster mutually beneficial international cooperation in space; (6) to create and expand opportunities for private sector activity in space; (7) to enable the evolution of the Space Station to meet future potential requirements and challenges; and, (8) to provide unmanned platforms exploiting station systems and subsystems design for long duration scientific and operation observations. The combination of manned, unmanned, and automated systems will establish a broad spectrum of capabilities responsive to both currently identified and evolutionary needs of space science, technology, and commerce.

Following completion of a three-year definition and advanced technology development phase, the development program was initiated in FY 1987. The selected revised baseline configuration includes a permanently manned Space Station, unmanned platforms, and the associated ground-based infrastructure. The major physical

elements of the configuration to be developed by the U.S. include pressurized habitation and laboratory modules, with a shirt-sleeve environment for crew habitation and for conducting experiments under microgravity conditions; resource nodes linking the modules in which command and control, docking and extravehicular activity (airlocks) functions will be based; high power polar arrays; a truss structure featuring accommodations for attached payloads and the FTS; pressurized and unpressurized logistics elements; extravehicular capabilities; and, a polar platform carrying Earth observing system instruments to be developed under the Space Science and Applications program. The configuration includes elements provided by the program's international partners. These elements are the Japanese experiment module, which includes a pressurized laboratory, an exposed module for payloads, and a logistics module; the Canadian Mobile Servicing System; and, the ESA's pressurized laboratory, polar platform, and man-tended free-flyer. The Space Station will be able to support a crew of eight and provide a total average power of not less than 75 kilowatts, using photovoltaic arrays.

The ground-based infrastructure needed for the development and operation of the Space Station include the development of capabilities for systems engineering and integration, a distribution system for technical and management information transmission, software development tools, prelaunch processing, mission operations, engineering support, integrated testing, and payload operations support.

The management of U.S. Space Station hardware elements design and development is led by four NASA field centers. The Space Station Program Office (SSPO), located in Reston, Virginia, has the task of managing and integrating the technical development of the entire program. The four "work package" centers are the Marshall Space Flight Center (GSFC) in Greenbelt, Maryland; and the Lewis Research Center (LeRC) in Cleveland, Ohio. While not work package centers, the Kennedy Space Center (KSC) at Cape Canaveral, Florida and the Langley Research Center (LaRC) in Hampton, Virginia have key Space Station responsibilities. KSC has the responsibility for Space Station prelaunch processing and post-landing activities plus a major role in logistics and user integration support while LaRC provides major support in systems engineering and integration. The Jet Propulsion Laboratory (JPL) in Pasadena, California, will also play a central role in defining Space Station program requirements and conducting independent assessments. NASA's development strategy for the Space Station deliberately precluded utilization of a single prime contractor. For a program of such extended duration as the Station, dependency upon one company was not viewed as being in the best interest of the government. Moreover, the work package approach better utilizes NASA expertise at the field centers and fosters greater competition among U.S. industry. An essential component of this strategy is that NASA will have the responsibility to perform the overall systems engineering and integration and program management. The SSPO is being assisted in these program-wide integration functions by a Program Support Contractor (PSC), a Software Support Envi-

ronment (SSE) contractor and a Technical and Management Information System (TMIS) contractor.

In 1987, the development contractors for the Space Station were selected. In May 1987, Boeing Computer Services was selected for the TMIS contract. This contract will facilitate both program control and engineering by enabling the electronic transmission of information and providing a means of distributing, maintaining, and archiving controlled data throughout the program. In July 1987, Grumman Aerospace was selected as the PSC. Grumman and its team supports NASA in a variety of areas, including systems engineering and analysis, distributed systems integration, technical integration, element and launch package integration, user interface planning, and program management and control. Also in July, 1987, the Lockheed Missiles and Space Company was selected for the SSE system contract. The SSE system is designed to assure a standardized software development and maintenance environment, in order to minimize the development and cost risk inherent in the task of integrating flight and ground systems software developed by a variety of Space Station contractors. On December 1, 1987, NASA announced selection of four aerospace firms—Boeing Aerospace Company; McDonnell Douglas Astronautics Company; General Electric Company; and the Rocketdyne Division of Rockwell International—for final negotiations leading to award of contracts for the design, development and support of the components and systems comprising the permanently manned Space Station. Letter contracts were awarded to these four companies on December 23, 1987 and the final detailed contracts were signed September 28, 1988. During the letter contract period, the contractors began planning for the initiation of their respective work package preliminary design and development efforts. They also supported the work package centers in the evaluation of the PRR and participated in the planning and working groups that have been formed to allow the various program elements and participants to share information. Due to the complexity of this enormous effort, it soon became apparent that a mechanism was needed which would allow the contractors to work together to achieve the common goal of building the Space Station to specifications, on schedule, and within the available funding. To satisfy this need, the Space Station program instituted associate contractor agreements among the contractors. They will have the responsibility, with NASA work package center and SSPO oversight, for coordinating the integration of their efforts in a timely and cost-effective manner and for delivering to NASA the required integrated hardware and software.

The development program also includes critical supporting development activities at the four NASA work package centers, and the development of the capability to operate and utilize the Space Station. Work package supporting development includes design engineering, hardware integration and test capabilities, and assembly and checkout test capabilities; the provision of Government Furnished Equipment (GFE); research and development (R&D) facility outfitting; and, engineering management and analysis. These efforts support all of the work package prime contractors as well as overall NASA system engineering and integration efforts. The Operational and Utilization Capability Development (OUCD) activi-

ties support major operational facility development at the NASA work package centers and KSC. These facilities are critical to the integration, prelaunch/post-landing processing, and the missions operations and crew training of the Space Station Systems.

Due to budgetary reductions and constraints made by Congress in the FY 1988 and FY 1989 appropriation processes, Space Station development activities will build up at a slower pace than originally planned. The Space Station Preliminary Design Review (PDR), which will provide an evaluation of the design approach of the work packages, will slip from FY 1989 to FY 1990. Successful completion of the PDR will result in the readiness to proceed with detailed design of the SSF flight and ground hardware and software. The Critical Design Review (CDR) is currently planned to occur in FY 1992. The first element launch is planned for March of 1995, man-tended capability in the fourth quarter of 1995, permanent manned capability planned in the fourth quarter of 1996, and assembly complete in the first quarter of 1998.

Management and integration

Elements of the SSF are being designed and developed by NASA centers and contractors throughout the U.S. as well as by the Canadians, Europeans, Japanese, and their contractors. Coordinating and integrating all of these various activities requires a comprehensive management and integration program effort by the SSF Program Office (SSFPO). Management responsibilities include: overall program management and direction; systems engineering and design; management of technical and administrative information; systems software environment design and development; safety, reliability, maintainability, and quality assurance activities; and integration of the United States and international systems and elements.

The broad scope and large magnitude of the Space Station program requires that NASA be supported by contractors knowledgeable in overall systems design, engineering, and integration. To achieve this goal NASA undertook a competitive procurement and in FY 1987 awarded a program support contract (PSC) to Grumman Aerospace Corporation, Bethpage, New York. Grumman is supporting not only the SSFPO in Reston, Virginia, but will also have personnel resident at the work package centers to assist them in their program integration activities. As the program support contractor, Grumman has responsibility for supporting overall Space Station systems engineering and integration activities. This includes providing the engineering manpower necessary for total systems configuration analysis and integration, design trade-offs, and operational analyses. They also assist in evaluation of technical performance across the program and perform program schedule integration. The PSC develops technical plans and procedures for the verification, assembly, and integration of the overall Space Station system and assists in the assessment of hardware/software systems developed by the work package prime contractors.

During FY 1989 the PSC will provide support for the completion and implementation of studies and analyses resulting from the PRR which was conducted during mid FY 1988. They will also be heavily involved in all of the activities necessary for supporting the

Preliminary Design Review (PDR) for the man-tended configuration. This PDR is scheduled for late FY 1990. Implementation of a program-wide technical and management information system (TMIS) is a significant part of the management and integration activity. The size and complexity of technical and management information that must be shared across all elements and levels of the SSFO requires the development of an advanced information system that can expeditiously handle the flow of this data. In June 1987, Boeing Computer Services was awarded a system integration contract to provide TMIS. TMIS is the official repository of technical and management information throughout the life of the SSFP. It provides a common methodology for tracking, updating, and disseminating SSFP documentation. TMIS facilitates and provides electronic transfer of a variety of program data among all the participating NASA centers and contractors. It will also allow NASA to electronically transfer appropriate program data to compatible information systems of the international participants. The initial increment of TMIS hardware and software was delivered in June 1988, and most recently, the initial increment of TMIS hardware and software was delivered in June 1988, and most recently, the initial hardware-to house data bases was installed.

Another important component of the management and integration effort is the design, development, and application of compatible flight and ground support software. To ensure compatibility across the various elements of the Space Station information system, NASA awarded a contract to the Lockheed Missiles and Space Company for the development of a software support environment (SSE). Lockheed is tasked to develop the software tools, rules, and standards that will be common to all Freedom Station flight and ground support users in their software development efforts. SSE has developed the initial SSE Development Facility (SSEDF) which is providing SSE equivalent basic software life cycle support capability to available main frame computer hardware. Currently, SSE has started developing prototype simulation interface buffers (SIB) which are software controlled multiport interface systems used to interface SSE host computers with data management system (DMS) kit flight system hardware. The contractor is also in the process of delivering seven software production facilities and will be bringing them on line to support the preliminary and critical design reviews.

A key management and integration activity occurring in FY 1990 will be the evaluation of project level system and element PDRs. These PDRs will be the basis for the program level PDR for the man-tended capability to be held in late FY 1990. PSC will be assisting NASA in this effort as well as in developing integrated schedules, verification plans, interface control documentation, and engineering data bases. Also during this period, the PSC will provide engineering support to the development or program plans for launch package integration, on-orbit assembly and checkout, NSTS integration, design reference mission and mission integration, and system safety and quality assurance program planning. This critical system engineering effort will be in support of the Reston SSPO, the Program Integration Offices at each work package center and at KSC.

During FY 1990, the SSE will achieve its initial operational capability and be delivered to the multi-system integration facility. The SSE project will complete development of the first simulation interface buffer (SIB). Subsequently, data management system (DMS) kits including SIB and DMS hardware, provided by Work Package 2, will be installed in the SSFDF so that full development and testing of SSE integration, test and verification capabilities can proceed. To further the development of the SSE operational system, the functional simulator (FSIM) will start to provide a capability for Space Station Program software developers to simulate the Space Station DMS system software services.

TMIS will continue to incrementally deliver releases of its products and will be working closely with all levels of the program to assure the most efficient and comprehensive exchange of information. Efforts will continue towards completion of the various bridges needed to electronically link together the contractors, NASA centers, users, and international partners as well as provide training to TMIS users as the system evolves. Technical and resource information management and tracking systems and data bases will continue to be developed with emphasis in Increment 2 on the efforts needed to support the SSFPO PDR process. Increment 2 will focus on completing TMIS rules and procedures, stabilizing and refining Increment 1 tools, providing a significant increase in data base and electronic mail host capacity, integrating data bases containing both technical and management data, and providing the first delivery of computer aided design/computer aided engineering (CAD/CAE) capability for the program. Increment 3 efforts will be targeted toward the development of applications and capabilities needed to support the SSFPO CDR process.

Pressurized modules

Work Package 1 is being managed by MSFC, Huntsville, Alabama with support from its prime contractor, Boeing Aerospace Corporation. Boeing was awarded a letter contract on December 23, 1987 and signed a negotiated contract on September 29, 1988. Assisting Boeing as major members of the prime contract team are Teledyne Brown Engineering (Huntsville, Alabama), Lockheed Missiles and Space Company (Sunnyvale, California), Hamilton Standard (Windsor Locks, Connecticut), Allied Signal Aerospace (Torrance, California), Grumman Aerospace Corporation (Houston, Texas), ILC Space Systems (Houston, Texas), and Fairchild-Weston Systems (Syossett, New York).

Major components of this package include the U.S. laboratory, habitability, and logistics modules; nodes structure; airlock systems; environmental control and life support system; internal audio, video, and thermal systems; basic module outfitting; and associated software development.

Since the initiation of the development phase of the Space Station Freedom (SSF) program, emphasis has been placed on the preparation of the plans and procedures that will be needed to design, develop, build, test, integrate, launch, and operate the Station. Included in these activities are the development of the engineering breadboards, trade studies, hardware build, and technology demonstration of the environmental control and life support

system; design and development of the module mock-ups; and evaluation of computerized structural models of the module components. Also ongoing is the evaluation of critical materials to be used in and on the Station and the design and development of computerized data bases that will be used to track and analyze the extensive test and evaluation results. As is the case with developing programs, much of the initial activity is in preparing the planning documents that will guide the development through its various stages. These plans and procedures are currently in the process of being baselined and will be updated as needed throughout the life of the Space Station program. With the recent completion of the PRR, efforts will not proceed toward implementation of the preliminary design leading toward the preliminary design review in FY 1990.

FY 1990 is a significant year for Work Package 1 because it is the year in which preliminary design reviews are planned to take place for all the major systems and elements needed for manned capability. Upon completion of these preliminary design reviews, prime contractor efforts will begin on the final design leading to critical design reviews in FY 1991 and FY 1992. The environmental control and life support system comparative technology testing which began in FY 1989 will continue and efforts will begin on the testing in the Core Module Integration Facility (CMIF). In the area of resource nodes and airlock systems, work will begin or continue on the support equipment component testing, cupola preliminary design, tool and production planning, and material procurement for structural test articles. The U.S. laboratory engineering development article will be completed and development hardware and software fabrication and test will begin. Work will continue on the preliminary design of the habitation module unique functions as well as preparation for and support of formal customer reviews. During FY 1990, there will be a review of all cargo requirements for the logistics modules as well as development of the concepts for accommodation of specimen, carriers, and subsystems. Work will continue on the development tests for logistics unique hardware and on defining the interfaces unique to the logistic modules with the orbiter, the station, and the cargo.

In the area of supporting development, system testing will continue utilizing the process material management system breadboard, the audio/video breadboard, and the electrical power system breadboard. Integrated environmental control and life support system testing will be completed and the node structural test article critical design review will be held leading to the start of fabrication. By the end of FY 1990, most of the developmental testing will be completed and hardware builds by the prime contractor will be initiated.

Assembly hardware/subsystems

Work Package 2 is managed by JSC with support from the prime contractor, McDonnell Douglas Corporation. The letter contract for this effort was awarded to McDonnell Douglas on December 23, 1987, and the final negotiated contract was signed on September 28, 1988. Assisting McDonnell Douglas as major members of the contract team are IBM (Houston, Texas and Owego, New York),

Lockheed Missiles and Space Company (Houston, Texas and Sunnyvale, California), General Electric/RCA Corporation (Camden, New Jersey), Honeywell (Clearwater, Florida) and Astro Aerospace Corporation (Carpinteria, California).

Work Package 2 responsibilities include the integrated truss assembly, mobile transporter, airlock structure and unique equipment, outfitting of the resource nodes, and the propulsion system. Also included in Work Package 2 are the data management system, communications and tracking; guidance, navigation and control, extra vehicular activity systems, thermal control, mechanical systems, fluids, and utilities distribution.

Much of the effort taking place since letter contract inception has been in formulating the plans, procedures, and design concepts that will be utilized for the development of the Work Package 2 elements and systems. The recently completed PRR lays the groundwork for finalizing the program requirements and efforts are now underway to baseline these requirement and proceed toward their implementation. Work is currently underway and progressing toward the development of test beds needed to evaluate design concepts, design and trade studies, facility requirements, and subsystem requirements. JSC personnel have been working with the Canadians to coordinate their mobile servicing center with the mobile transporter. Work is also progressing on design of the Space Station Extravehicular Mobility Unit with a prototype suit to be evaluated during FY 1989. Plans for the procedures, hardware, and software needed for on-orbit assembly are continuing and Shuttle/Station berthing and docking concepts are being investigated and tested. Also ongoing is the design and development of the flight experiments that will be needed to test various concepts and hardware prior to their use on the SSF. These flight experiments will, among other things, test thermal systems, navigation, and control, and the Space Station EVA suit.

The major milestone in FY 1990 is the preliminary design review of the systems and elements needed for man-tended capability. JSC and its contractors will be holding project design reviews for its elements and systems during the third quarter of the fiscal year in preparation for the program design review planned for the fourth quarter. There is a great deal of design, analysis, and test work that must be performed prior to these reviews. Much of this effort will have been initiated in FY 1989 but will become more intensive during 1990. The prime contractor will finish preliminary design work and begin the task of detailed design. Development testing will continue and work will begin on the procurement, fabrication, and assembly of the data management system hardware and software, the thermal control system, the mobile transporter, and the airlocks. The prime contractor will also continue to support the various working groups and panels that are responsible for coordinating the efforts of the program participants and will perform studies as directed by JSC and the SSPO.

JSC will also continue its supporting development efforts in preparation for the preliminary design review. They will begin integrated loads/dynamics truss analysis and thermal vacuum chamber solar outfitting. Verification tests will be performed on the antennas and work will continue on the prototype electrolysis unit fabri-

cation and test. Efforts will continue in preparation for thermal flight experiments and refinements and testing of the AX5/Mark III space suits should be completed. In addition, utilizing the KC-135 airplane, tests that require a space-like environment will be performed.

Platforms and servicing

Work Package 3 is being managed by GSFC, Greenbelt, Maryland with support from its prime contractor, The General Electric Company, Astrospace Division, Valley Forge, Pennsylvania, and East Windsor, New Jersey. General Electric was awarded a letter contract on December 23, 1987, and signed and negotiated contract on September 28, 1988. The TRW Corporation of Redondo Beach, California, is the major subcontractor to General Electric.

Included, in Work Package 3 is the design and development of the free-flying, unmanned U.S. polar platform; the attached payload accommodation equipment (APAE) for the mounting of various scientific instruments on the manned base; and a payload pointing system (PPS) for both Earth-viewing and space-viewing attached payloads that require a high degree of accuracy. Also included are early studies of the design, requirements, and interfaces necessary for a satellite servicing facility that could be used to service SSF payloads and free-flying spacecraft. Development of a servicing facility is a potential future consideration. A key component of this work package is an ongoing interaction with potential users of the Space Station. Understanding the needs of potential Space Station users and including them in all of the pertinent planning activities is vital to the design, development, and operation of the station.

A major activity taking place at Work Package 3 during FY 1990 is the PDR for the polar platform. Upon successful completion of the PDR, detailed design, testing, long-lead procurement, and fabrication of the platform will begin. Preliminary design and requirements definition of the attached payload accommodation equipment and the payload pointing system will continue during FY 1990. Studies of servicing facility architecture will continue, and servicing scenarios for selected payloads will be developed.

Supporting development activities at GSFC will include continuing engineering and discipline support for the platform, APAE, and PPS. Base motion studies for the PPS will be conducted. Discipline support for the safety, reliability, and quality assurance area will continue. As part of the thermal program, development of a data management system test bed, an instrument test bed, and NSTS thermal flight test experiments will continue. Design and requirements definition for an Integration, Test, and Verification Facility at the GSFC will be initiated. This facility will provide a clean environment for the checkout of the attached payloads and the polar platform with the physical, electrical, and thermal interfaces.

Power system

Work Package 4 is managed by the LeRC and supported by its prime contractor, Rocketdyne Division, Rockwell International (Canoga Park, California). Supporting Rocketdyne as major members of the contract team are Ford Aerospace (Palo Alto, Califor-

nia); Harris Corporation (Melbourne, Florida); Allied-Signal Aerospace Corporation (Tempe, Arizona); General Dynamics Corporation (San Diego, California); and Lockheed Missiles and Space Company (Sunnyvale, California). Rocketdyne was awarded a letter contract on December 23, 1987, and signed the negotiated contract on September 28, 1988.

The primary content of Work Package 4 is the SSF Electrical Power System. This encompasses the development of a 75 KW photovoltaic (PV) power system which uses solar arrays to collect power and batteries for storage; the power management and distribution (PMAD) system; engineering and system architecture of a solar dynamic power system capability which could be a future addition to the station; and the fabrication of power system components for the polar platform.

The electric power system will be one component of the first element launch and therefore hardware must be ready for delivery at that point in the program. System and sub-system design and development are actively being performed by the contractor team and by the Lewis supporting development personnel. Component testing of the batteries and solar cells began in FY 1988 and will continue into FY 1989 in preparation for the preliminary design review in FY 1990. Test beds for both photovoltaic power and the power management distribution system have been developed and are being utilized. The Power System Facility and the Space Power Facility are in the process of being made ready to begin testing and work has commenced on developing an integrated test bed. Work is also proceeding in preparation for proof-of-concept testing of the solar dynamic power system.

During FY 1990 efforts being performed by the prime contractor and LeRC teams will intensify in preparation for the project and program preliminary design reviews. Rocketdyne will continue with development and qualification of the solar cells and blankets. Energy storage assembly qualification cells will be fabricated and tested. Preliminary and detailed design of module items such as beta gimbals and electrical equipment assemblies will continue as will the preliminary design effort for the solar dynamic power. Power management and distribution components and orbital replacement units will undergo preliminary and then detailed design during FY 1990 and development and testing of breadboard and brassboard components will continue.

Supporting development activities complement those being performed by the contractor and include the independent verification of the prime systems engineering and integration efforts. Also included in supporting development is the design and provision of the interfaces with the SSE and the Space Station Information System. Key work will continue utilizing the existing PV/PMAD testbed and the PMAD systems testbed and efforts will begin on preparation of the integrated testbed. These test and evaluation activities will culminate in the development of a preliminary design which will then be reviewed in the latter part of FY 1990 as part of the overall program preliminary design review.

Operations/utilization capability development

The purpose of the Operations/Utilization Capability Development (OUCD) program is to develop a set of operational facilities, systems, and capabilities to conduct the operations of the SSF. The majority of the work will be performed at KSC, MSFC, and JSC, although key operational capabilities will be developed at other NASA centers. KSC will develop launch site operations capabilities for conducting prelaunch and post-landing ground operations for the SSF. These capabilities will include the development of the Test, Control and Monitor System (TCMS) to provide real-time checkout, control and monitoring functions during processing of SSF elements at KSC and the Vandenberg Launch Site (VLS) prior to launch. Prelaunch and post-landing ground operations will occur in the Space Station Processing Facility (SSPF) and other key facilities, including the Space Station Hazardous Processing Facility (SSHPPF) at KSC and the Platform Processing Facility at Vandenberg.

MSFC will develop user integration capabilities to establish user requirements and perform user operations support. Efforts will include the development of the Payload Operations Integration Center (POIC) and the Payload Operations Training Facility (POTF), as well as extensive payload mission planning and analytical integration. The major objective at JSC is to develop space systems operations capabilities for conducting training and on-orbit operations control of the SSF. Efforts will include the development of the Space Station Control Center (SSCC), the Space Station Training Facility (SSTF), and the Operations Planning and Analysis System (OPAS). LeRC will provide an Engineering Support Center (ESC) for the power system, and GSFC will provide an ESC for attached payloads and special outfitting for the Platform Control Center. Each of these centers will be involved in user integration activities and operations planning efforts.

Work is currently underway to develop facility requirements and outfitting needs and to develop the mission planning and user interfaces. The prime contractors associated with the four work packages are assisting in these activities since the design, development, and operation of the station are so strongly interconnected. User input is being solicited and received and users are being kept informed of progress in all of the OUCD planning efforts. Astronauts are also included in this process and their input is an important part of the design and operations activities. Requests for Proposals have been released for the Control Center and Training Facility support at JSC and for the TCMS at KSC.

At KSC in FY 1990, the CAD/CAE contract and the TCMS avionics procurement will begin, and the PDR for the core design of the TCMS will be conducted. The procurement of ground support equipment for the SSPF will continue. At MSFC, design of the POIC and the POTF will continue, as will development of analytical integration software tools. Engineering studies for the POTF core computer will be completed and procurement initiated. At JSC, requirements definition and design of the SSCC and the SSTF will continue. The PDR will be held for the SSCC, and for the OPAS. LeRC and GSFC will continue design of their ESCs, and

GSFC will continue platform and attached payload analyses and user accommodation studies.

FLIGHT TELEROBOTICS SERVICER

Flight telerobotics servicer:

1989 current estimate.....	\$46,000,000
1990 budget request.....	15,000,000

The Flight Telerobotics Servicer (FTS) will be a highly automated, robotic flight system capable of precise manipulations in space. It can be operated by astronauts at work stations aboard the space station or the shuttle by either direct manipulator control or programmed command sequences. Its hardware and software will be modular to ensure serviceability, and its configuration will be flexible to accommodate technological upgrades and growth to autonomous operation. The FTS will be capable of performing EVA tasks such as assembly, inspection, maintenance, and servicing. By reducing dependence on EVA, it will improve crew safety and enhance crew utilization. The FTS will be designed to attach to several hardware elements, such as the Shuttle's Remote Manipulator System; utility ports along the SSF truss; the Orbital maneuvering Vehicle; and SSF platforms. The knowledge NASA gains using the FTS in space will be used to facilitate the transfer of automation and robotics (A&R) technology to U.S. industry.

The FTS is being proposed as a commercial development. Project management is the responsibility of GSFC, with support from other NASA centers and contractors. The major elements of the program include the Space Station FTS (SSFTS), or telerobot flight unit, which will be available at FEL, and will be launched on the second assembly flight; the Development Test Flight (DTF-1); the Demonstration Test Flight (DTF-2); and the Engineering Test System (ETS). Supporting development activities at GSFC and other NASA centers will identify and utilize developing automation and robotics technologies to meet FTS requirements and improve FTS performance and will support the transfer of demonstrated capabilities and technology concepts to commercial applications.

The DTF-1 is planned to be flown aboard the NSTS in late 1991 and will consist of two telerobot manipulators, a carrier structure, task elements, and a workstation. Using existing technology, DTF-1 will evaluate FTS design approaches and man-machine interfaces. In September 1988, nine-month letter contracts for \$4.5 million each were awarded to the Martin-Marietta Corporation and to Grumman Aerospace for preliminary design of DTF-1. These contracts provide for initiation of long-lead procurement items and for delivery of all analyses and documentation required to support a PDR for DTF-1, currently planned to be held in mid-1989. The DTF-2 will consist of a mature version of the SSFTS, a carrier structure, task elements, flight support equipment, and a workstation, to be flown aboard the NSTS in early 1993. DTF-2 will demonstrate FTS capabilities prior to SSF deployment.

The ETS will be a ground test system for FTS software development and verification; for dexterous task planning and verification; and for flight anomaly investigation. It will consist of a telerobot,

multipurpose end-effectors and tools, ground support equipment, and spares.

In September 1988, the FTS Phase B contracts with Martin-Marietta and Grumman were completed. A GSFC review of the results is in progress. The RFP for Phase C/D of the FTS was issued in November 1988, with proposals due in January 1989.

In FY 1990 NASA is actively pursuing approaches to encourage the private sector to invest in the FTS. The requested funding will provide for supporting development activities.

Supporting development activities in FY 1990 include crew training, flight operations support, and integrated flight simulations. Studies of OMV interfaces verification will continue. Efforts will continue on applications procedure development, and technology assessment and testing.

OPERATIONS

Operations:

1990 budget request	\$25,000
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OBJECTIVES AND STATUS

Planning for operations and utilization has been an integral part of the SSF design and development program and a major driver in the approaches established for Station assembly, utilization, and evolution. As a long-term permanently manned laboratory in orbit, Freedom will be serving the needs of many disciplines and individuals, and must be designed and operated to be safe, reliable, and accommodating to numerous diverse uses. It must also be cost-effective to operate, economical to utilize and amenable to changes in technology that will be occurring during its planned 30 years in space. The various elements of the development program such as flight systems hardware/software production, operations/utilization capability development, and management and integration will transition, over time, into the components of the operations program. These components include flight and ground hardware and software sustaining engineering, integrated logistics support, user integration and operations support, space system operations support, prelaunch and post-landing operations, and information system services operations.

BASIS OF FY 1990 ESTIMATE

Although some planning for operations is ongoing within the development program under operations/utilization capability development, FY 1990 is the first year that funding is required for items that are included in the operations budget of the program. During FY 1990 much of the effort will consist of initial planning for integrated logistics operations and space systems operations. Logistics activities will focus on logistics management and maintenance planning and early planning for initial spares for flight hardware and support equipment. Space systems operations activities will include the study and initiation of the assembly planning tasks.

TRANSITION DEVELOPMENT

Transition definition:

1989 Current estimate.....	\$12,000,000
1990 Budget request.....	25,000,000

The February 11, 1988, Presidential directive on National Space Policy states that the "Space Station will allow evolution in keeping with the needs of Station users and the long-term goals of the United States." This policy encapsulates the goal of the Transition Definition program and reaffirms the NASA approach to the program since its inception: to design and build a facility that is capable of expanding original capabilities, adding new functional capabilities, and incorporating improved technologies. SSF design reflects consideration of an extended operational lifetime in support of a changing and growing user community.

There are two elements to the Transition Definition program: system studies and analyses; and advanced development. The strategy is to focus these interrelated elements on understanding probable evolution paths and the implications of these on current decisions in the baseline program. Possible evolution paths include: expansion of multi-disciplinary research activities in low Earth orbit, mission to planet Earth, piloted exploration missions, and unmanned planetary missions. The challenge to provide for Station evolution is to keep open options to support whatever future missions may be chosen. Therefore, planning for evolution is by necessity conducted in parallel with the design and development of the baseline Station.

The objectives of the system studies and analysis portion of the program are to concentrate on defining Space Station concepts to support the Human Exploration Missions, the Mission to Planet Earth studies, the continued growth of a multidiscipline Space Station, as well as to identify technology needs. Another important objective is to define and incorporate "scars and hooks" in the baseline program to preserve the capability for evolution.

The specific objectives of the SSF advanced development program are: (1) to enhance baseline Freedom capabilities with an emphasis on increasing productivity and reliability; (2) to reduce operations costs; and (3) to enable Space Station Freedom evolution by providing mature technology in areas required to support advanced missions.

The key FY 1990 activities are directly related to the upcoming program PDRs. In the near-term, the Transition Definition program is aimed at defining required "hooks and scars" prior to the start of PDR activities. What remains to be accomplished in FY 1990 is evaluating these design provisions at Level I, II, and III Change Boards.

During FY 1990, system studies and analysis efforts will build on previous work by narrowing the number of evolution concepts under study. The reference concepts will then undergo feasibility studies at the pre-Phase A level. These studies will include operations analyses to establish the system level implications for the evolution of Station operations and utilization. Special emphasis will be placed on identification of technologies necessary to enable evolution. Thus, a major product of the Transition Definition pro-

gram is definitized concepts at the system level that will accommodate the mission requirements posed by NASA program offices.

The advanced development program for FY 1990 has two major thrusts: application development and demonstrations, and technology development and evaluation. Tasks under application development and demonstration address the application of knowledge-based system (KBS) technology to on-orbit system control, ground operations support, and the Space Station information systems. The task set for 1989-1990 is aimed at understanding the "hooks and scars" associated with the application of KBS techniques to thermal, electrical power, reaction control, health maintenance, scientific experimentation, data management, command and control, and environmental control and life support systems. Tasks under technology development and evaluation address advanced automation software development, advanced computational hardware and environments, human factors, and robotics systems integration and accommodation. Central to tasks under both thrusts are system engineering issues associated with the integration of KBS applications with conventional automation techniques; requirements for on-board data processing, storage, and communications capacity; software development, testing, and maintenance; and the identification of the boundaries of KBS performance in terms of execution speed and application complexity.

ORBITAL DEBRIS RADAR

Orbital debris radar:

1990 budget estimate.....	\$15,000,000
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This is the first SSF program budget submission for development and construction of an orbital debris radar. Prior to FY 1990, a study effort was being funded by the Office of Space Flight, Advanced Program Office.

To address the growing national concern over the hazard posed by orbital debris to the space activities of the U.S. requires information of two types: (1) long term monitoring of the small size debris to quantify the trends in debris population, and (2) characterization and assessment of small size orbital debris. Since the SSF is planned to be in orbit for as much as thirty years, it is absolutely vital that the pressurized elements be designed and development to withstand as much of the orbital debris effects as possible. This requires the construction and operation of a radar system that can both quantify and characterize this debris.

The required information for Space Station is the population of one centimeter diameter debris particles (limit of size which can be protected with shielding on the Station). Currently this information is not available for other sources. Preliminary experiments have suggested that the population of this size particles may be higher than expected, but to get definitive information, additional measurements with the proper characteristics in a different frequency band are needed.

The radar consists of a ten meter antenna and associated hardware and software to be built under a competitive contract and managed by the Jet Propulsion Laboratory. The exact location of the radar has not yet been determined but ideally it should be as

close to the equator as possible in order to cover a wide range of orbits. Once operational, the radar will be able to monitor objects as small as one centimeter in diameter orbiting at five hundred kilometers. It will determine the radar cross-section, altitude (plus or minus five kilometers), and the orbital inclination of the debris.

The current schedule for design and construction of the radar consists of a competitive contract award in July 1989, a 21-month design and construction period, and six month ship, install, and test period. This schedule would make the radar operational in October 1991. The key driver for maintaining this schedule is the design of the SSF pressurized modules. In order to affect this design, information from the radar analysis is needed prior to the critical design reviews, currently scheduled to occur in early 1992. Any delay in the initiation of the radar development will preclude availability of design data in time to influence the critical design efforts. Funding is needed in FY 1990 for the orbital debris radar design and construction work that will lead to obtaining the necessary data in a timely manner.

SPACE TRANSPORTATION CAPABILITY DEVELOPMENT

FY 1990 NASA REQUEST \$639,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Spacelab	\$88,600,000	\$98,900,000
Upper stages.....	138,800,000	88,600,000
Engineering and technical base.....	155,400,000	189,800,000
Payload operations and support equipment.....	64,700,000	81,100,000
Advanced programs	52,700,000	48,700,000
Advanced launch systems.....	81,400,000	5,000,000
Tethered satellite system.....	26,400,000	19,900,000
Orbital maneuvering vehicle	73,000,000	107,000,000
Total	681,000,000	639,000,000

The principal areas of activity in Space Transportation Capability Development include the Spacelab; the Upper Stages required to place satellites in high altitude orbits; the Engineering and Technical Base support at the manned space flight centers; Payload Operations and Support Equipment for accommodating NASA payloads; Advanced Programs study and evaluation efforts; Advanced Launch Systems efforts; the design and development of the United States/Italian Tethered Satellite System; and the development and first flight of the Orbital Maneuvering Vehicle.

Spacelab was developed jointly by NASA and the European Space Agency (ESA). It is a major element of the Space Transportation System (STS) that provides a versatile, reusable laboratory which is flown to and from Earth orbit in the orbiter cargo bay. The development program continues with a recertification program to insure flight safety, the procurement of flight hardware to support the flight program and necessary modifications including replacing the onboard computer system.

Upper Stages are required to deploy payloads to orbits and trajectories not attainable by the Shuttle or core stage expendable launch vehicles alone. The program provides for procurement of stages for NASA missions, for technical monitoring and management activities for government and commercial Upper Stages, and a solid rocket motor integrity program to establish an engineering data base for improving the success rate of U.S. built solid motors.

The Engineering and Technical Base provides the core capability for the engineering, scientific, technical and Safety, Reliability and Quality Assurance (SR&QA) support required at the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC) for research and development activities. Additional requirements above the core level of capability are funded by the benefiting programs.

The Payload Operations and Support Equipment program develops and places into operational status the ground and flight systems necessary to support the NASA STS payloads during pre-launch processing, on-orbit mission operations and, when appropriate, post-landing processing. Included within this program area are the STS optional services for NASA payloads, and multi-mission payload support equipment.

Advanced Programs conducts concept feasibility studies and selected system definitions and preliminary design (Phase B) studies and undertakes related high leverage advanced development to provide the technical and programmatic data to identify evolving space transportation and system requirements and to evaluate new space transportation initiatives. Complementary objectives are to assimilate generic technology and advanced planning activities, and to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices. Activity is focused on four major areas—advanced transportation, advanced operations support, satellite servicing and advanced missions. Concept definition and key advanced development are under way and planned in these areas to assess performance, reliability and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Included as part of the Advanced Programs Development Program are definition studies of a Assured Crew Return Capability (ACRC) to provide approaches for additional crew return capability from the Space Station manned base.

The Advanced Launch System (ALS), as outlined in the joint DOD/NASA Report to Congress, is a joint DOD/NASA program to develop and field this nation's next generation of unmanned launch system. The ALS program will permit this nation to achieve the goal of reduced cost to space. Both NASA and the DOD are moving aggressively forward with ALS and are jointly managing the effort. Consistent with the ALS agreement, the DOD includes funding for the joint programs in their budget submission. In FY 1988 and FY 1989, the Congressional appropriations transferred to NASA funding for the NASA managed portion of the joint effort. The FY 1990 request for the joint program is included in the DOD budget in anticipation of similar appropriations actions. NASA has requested separate funds for study efforts for

unique civil mission requirements not satisfied in the joint DOD/NASA ALS baseline design.

The Tethered Satellite System (TSS), a joint Italian/United States development effort, will provide a new reusable facility for conducting space experiments and unique tethered applications in regions remote from the Shuttle orbiter. The objectives of the initial TSS mission are twofold: (1) to verify the controlled deployment, operation, and retrieval of the TSS, and (2) to quantify the interaction between the satellite/tether and space plasma in the presence of an electrical current drawn through the tether.

The development of the Orbital Maneuvering Vehicle (OMV), initiated in 1986, will provide a capability for payload delivery, retrieval, and servicing beyond the reach of the Space Shuttle or the Space Station.

Four dedicated Spacelab flights have been flown on the STS including the first Spacelab reimbursable flight, Deutschland-1 (D-1). In addition, several smaller Spacelab elements have flown on other STS flights as partial payloads. These flights have demonstrated the unique capabilities and benefits offered by many of the Spacelab elements. The Spacelab Astro-1 mission, scheduled for the first quarter of CY 1990, will be the verification mission of the Igloo Pallet Configuration of the Spacelab Pallet System (SPS). The Enhanced Multiplexer/Demultiplexer Pallet (EMP) will be verified with the tether satellite system mission. Preparations are now in process for resumption of Spacelab operational flights for DOD, international, and NASA scientific experiments.

In Upper Stages, funding is included for production, launch, flight support, and integration of Inertial Upper Stage (IUS) vehicles to accommodate the TDRS E and F missions, and the Magellan, the Galileo and Ulysses (including a PAM-S vehicle) planetary missions. The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit.

The Transfer Orbit Stage (TOS) is a three-axis stabilized perigee stage that is being commercially developed by the Orbital Sciences Corporation for use with the Shuttle or on Titan III. It will have the capability of placing up to 13,000 pounds into geosynchronous transfer orbit. Production, integration and launch operations for a TOS vehicle for the Mars Observer (MO) is included in the FY 1990 budget. MO will be launched on a Titan III. Funding for a second TOS stage for the Advanced Communications Technology Satellite (ACTS) mission, proposed for termination in the budget, is included through FY 1989 only.

The Solid Propulsion Integrity Program (SPIP) objective is to establish the necessary engineering capability for improving the success rate of U.S. manufactured solid rocket motors. The initial phase of the program, started in 1984, has made excellent progress in determining root causes and solutions to the persistent problems plaguing motor nozzles. The results and findings have been used in the Shuttle Solid Rocket Motor redesign effort. The program scope is being expanded to examine motor bondlines as well as continuing the nozzle efforts.

In Payload Operations and Support Equipment, payload integration support and payload-related hardware are developed and fur-

nished for NASA payloads. Multi-mission payload support equipment is developed and procured including fiber optic cabling and equipment for communication links between the payload processing facilities; standard sets of wire harnesses for interconnection of mixed cargoes in the orbiter payload bay; and payload displays and controls in the orbiter vehicle crew cabin.

In Advanced Programs, concept definition and key advanced development are underway to assess performance, reliability, and operational efficiency improvements, and to reduce future program risks and development costs through the effective use of new technology. Advanced transportation study efforts focus on cargo vehicles, manned vehicles, and space transfer vehicles. Studies are underway to define the evolution of manned vehicles, including Space Shuttle enhancement concepts (Shuttle Block II), and next generation concepts (Shuttle II). In addition, definition studies are underway to analyze mission requirements for the design and development of an assured crew return capability (ACRC) from the Space Station. Advanced operations support systems efforts focus on the study and assessment of innovative ground, flight and on-orbit operations techniques to achieve improved safety as well as reduced life-cycle costs for space transportation and orbital systems. The complementary Advanced Operation Effectiveness activity will focus on demonstration of autonomous and expert systems technology to improve the safety and reduce the costs of Shuttle operations. The satellite servicing study effort, encompassing satellite servicing systems and tether applications, focuses primarily on the development of systems and procedures designed to utilize Shuttle capabilities that are compatible with the Space Station and the Orbital Maneuvering Vehicle. Advanced missions activity will continue to focus, with expanded scope and increased depth, on potential manned and unmanned missions beyond the Space Station. Focused orbital debris studies, augmented by the development of a debris measurement radar by the Office of Space Station, will be continued.

Studies, with a directed focus building upon the joint DOD/NASA Advanced Launch System (ALS) baseline design, are planned to examine vehicle and propulsion systems to satisfy national requirements. The ALS-Propulsion Focused Technology program, a NASA-managed element of the core DOD/NASA ALS program, is focused on demonstrating the performance and operating capabilities of critical propulsion system components. FY 1990 funding for continuation of this effort is included in the DOD budget request.

The Tethered Satellite System (TSS) will provide a Shuttle-based facility for electrodynamic and upper atmospheric research. Hardware development was initiated in FY 1984 and systems definition studies were completed in FY 1985. Comprehensive design and requirements validation, procurement of flight hardware elements and tooling, systems development and integration, and deployer manufacturing and integration will continue through 1990. The Italians started satellite and core equipment development in FY 1984. U.S. science instruments for the satellite are being funded in the Space Science and Applications budget. A cooperative first

flight for systems validation and electrodynamic research is presently planned for 1991.

The Orbital Maneuvering Vehicle (OMV) is a reusable, remotely operated space tug with the capability to deliver, retrieve and service payloads and spacecraft deployed from the Space Shuttle or Space Station over a wide range of altitudes and inclinations. The development contract was initiated in late 1986 with a planned initial capability in 1991. Based on budgetary reductions and current Shuttle manifest planning, the initial capability requirement has been rescheduled to FY 1994. Uses of the OMV will include supporting scientific experiments and tests and the Space Station as well as satellite servicing and reboost. The FY 1990 budget request includes funds for continuation of the design and development, initial testing, and production of flight hardware.

SPACELAB

	1989 current estimate	1990 budget request
Development.....	\$18,000,000	\$12,000,000
Operations	70,600,000	86,900,000
Total	88,600,000	98,900,000

The Spacelab is a versatile facility designed for installation in the cargo bay of the orbiter which affords scientists the opportunity to conduct scientific experiments in the unique environment of space. The reusable Spacelab system enhances the advancement of scientific research by serving as both an observatory and laboratory in space. Ten European nations, including nine members of the European Space Agency (ESA), have participated in this joint development program with NASA. ESA designed, developed, produced, and delivered the first Spacelab hardware consisting of: a pressurized module and unpressurized pallet segments, an Igloo which is used with pallets to supply equipment, computers and services essential to the experiments, an instrument pointing subsystem (IPS), and much of the ground support equipment and software for both flight and ground operations.

NASA procured an additional set of Spacelab hardware from ESA under terms of the ESA/NASA Memorandum of Understanding and the Intergovernment Agreement. The remaining NASA funded development activities include additional hardware to complete the Spacelab system, ground support equipment, hardware modifications, hardware acquisition, system recertification, and qualification and procurement of reliable and high capacity AP-101SL computers. Support software and procedures development, testing, and training activities not provided by ESA, which are required for the Spacelab, are also included in NASA's funding. Additional Spacelab hardware, including the initial lay-in of spare hardware, is being procured from European and U.S. sources.

NASA has developed two principal versions of the Spacelab Pallet System (SPS): one will support missions requiring the igloo and pallet in a mixed cargo configuration like the Astro series; the other version will support missions that do not require use of the

igloo such as the Space Technology Experiment Platform (STEP) and the Tethered Satellite System. Development of the Hitchhiker system is nearly complete. The Marshall Space Center (MSFC) version of the Hitchhiker will fly at the next available opportunity.

The Spacelab operations budget includes mission planning, mission integration, and flight and ground operations. This includes integration of the flight hardware and software, mission independent crew training, system operations support, payload operations control support, payload processing, logistical support and sustaining engineering.

Previous major Space missions include Spacelab-1 flown in FY 1984 and Spacelab-3 and Spacelab-2 which were flown in FY 1985. The first Spacelab reimbursable flight, Deutschland-1 (D-1), was flown during the first quarter of FY 1986. Astro-1, originally planned for flight in FY 1986 for observation of Halley's Comet, was delayed to FY 1990 due to the January 1986 Shuttle accident. The initial flight of the Goddard Space Flight Center Hitchhiker (HG-1) took place in the first quarter of FY 1986.

In addition to these missions, analytical and physical integration, configuration management, and software development for future flights will be conducted. Procurement of spaces for both NASA-developed hardware and for hardware developed by U.S. companies under contract with ESA will continue throughout FY 1989 and FY 1990 as will operation of the depot maintenance program for U.S.-provided and European-supplied hardware.

The FY 1990 request reflects an increase in the scheduling and frequency of Spacelab missions which had been significantly delayed by the Challenger accident. Funding provides for the integration and payload processing of three to four major and three to four secondary missions per year.

The FY 1990 development funds are required to procure additional computers and experiment hardware to support and accelerated and more active Spacelab traffic flow which otherwise would create hardware shortages. The Spacelab flight hardware recertification, the Hitchhiker programs, and the Enhanced Multiplexer Pallet System (EMPS) are scheduled for completion in FY 1990.

The FY 1990 operations funds are required to support payload operations and to continue payload integration support, mission independent training, and logistics support. This support includes analytical integration, configuration management, hardware integration and software development and integration. Spacelab operations also provides for replenishment spares, the operation of the depots for both U.S. and European hardware and software, and sustaining engineering of all hardware and software. Funding is also included for the Getaway Special (GAS) program which was transferred from Shuttle Operations in FY 1989.

In addition to continuing operations support of the Spacelab mission planned through FY 1991, FY 1990 funding is required to begin mission integration and payload processing support for the U.S. Microgravity Laboratory (USML) mission which is planned for flight in the second quarter of FY 1992.

In addition to NASA missions the Spacelab program will also support three (3) reimbursable missions: the U.S. DOD Starlab, the Japanese SL-J, and the German D-2. Appropriated funding is com-

bined with reimbursable funding to support the total Spacelab operations requirements. In FY 1990, \$11.0 million of reimbursable funds are anticipated.

UPPER STAGES

	1989 current estimate	1990 budget request
Development.....	\$4,900,000	\$400,000
Procurement and operations.....	133,900,000	88,200,000
Total	138,800,000	88,600,000

The STS upper stages are required to deploy payloads to orbits not attainable by the Shuttle or core stage expendable launch vehicle alone. The Inertial Upper Stage (IUS), and the commercially developed Payload Assist Modules (PAM-A, PAM-D and PAM-DII) are currently available for use. Several other upper stages are now being commercially developed, including the Transfer Orbit Stage (TOS), which will become available for use in the near future.

The IUS was developed under a DOD contract to provide the capability to place payloads of up to 5,000 pounds into geosynchronous orbit. The IUS has been launched from both the Shuttle and Titan 34-D Expendable Launch Vehicle. Six IUS vehicles are under contract for launch of the Tracking and Data Relay Satellite System (TDRSS) spacecraft. The first three were funded through the TDRSS contract while the others are funded under this budget element. TDRS-D, TDRS-E and -F remain to be launched on the Shuttle. In addition, IUS vehicles will be used for the Magellan, Galileo and Ulysses planetary launches.

A PAM is being procured as a kick stage in conjunction with the IUS for the Ulysses launch. This is the only PAM in the current upper stage budget since the remaining NASA spacecraft that require PAM stages are planned for launch on Delta launch vehicles. The PAM is procured as part of the Delta launch service and therefore is included in the Expendable Launch Vehicle budget.

TOS is a three-axis stabilized perigee stage that is being developed commercially by the Orbital Science Corporation for use with the Shuttle and the Titan III. It will have the capability to place 6,000 to 13,000 pounds into geosynchronous transfer orbit. One TOS/Titan III upper stage is being procured for the Mars Observer mission to be launched in FY 1992; funding of a TOS/Shuttle stage for ACTS is included through FY 1989 only.

The Solid Propulsion Integrity Program was initiated in FY 1984 to establish an urgently needed engineering data base for use of composite materials in upper stage motor nozzles, to minimize risk to planned missions and to restore user confidence in U.S. launch systems. Underlying root causes of persistent problems in motor nozzles have been identified and required data is being generated. Work to examine motor bondlines has been initiated, in addition to increasing the level of effort in motor nozzle studies. The results of this program will continue to be used in support of the Shuttle Solid Rocket Motor.

BASIS OF FY 1990 ESTIMATE

Development and Operations funds in Fy 1990 are required to continue progress on the IUS Upper Stages for TDRSS and for the Magellan, Galileo and Ulysses planetary missions and the TOS Upper Stage for Mars Observer. Funding has not been included to continue the TOS stage for ACTS. FY 1990 funds are also necessary to support continuation of the Solid Propulsion Integrity Program.

ENGINEERING AND TECHNICAL BASE

	1989 current estimate	1990 budget request
Research and test support	\$94,900,000	\$125,500,000
Data systems and flight support	16,900,000	17,400,000
Operations support	32,700,000	34,300,000
Launch systems support	10,900,000	12,600,000
Total	155,400,000	189,800,000

The Engineering and Technical Base (ETB) provides the program core capability required to sustain an engineering and development base for various NASA activities at the manned space flight centers. Additional center requirements above the core level are funded by the benefiting programs, such as Space Transportation Operations and Shuttle Production and Capability Development. The centers involved are the Johnson Space Center (JSC), the Kennedy Space Center (KSC), the Marshall Space Flight Center (MSFC), and the Stennis Space Center (SSC).

The core level of support varies from center to center due to programmatic and institutional differences. At JSC, the core level requirement is that one shift of operations be maintained in the engineering and development laboratories and the White Sands Test Facility. Safety, reliability and quality assurance (SR&QA) areas are also supported by the ETB core. The core level for the central computer complex is established as a two-shift operation. At KSC, the core level provides for research and development of technology to enhance launch site hardware, ground processing, support services; and SR&QA. ETB funds at MSFC provide for multi-program support activities, including technical labs and facilities, computational and communications services, and at SSC for test facility operations.

The requested funding for ETB in FY 1990 not only provides for a continuation of the FY 1989 level of support for required research and development facilities and services at the centers but enables necessary increases in the core for SR&QA requirements, upgrading of engineering labs and engineering support services with state-of-the-art technology and capability to meet critical requirements for technology development, and expanded Class VI computer capabilities at MSFC. FY 1990 funds will also support the first full year of operations of the Class VI computer capability at JSC.

In research and test support, funding is required to support SR&QA activities at JSC, MSFC and KSC. In addition, computational capabilities at MSFC are provided for engineering and science projects through the use of a Class VI computer system. This capability is required for the solution of complex main engine three-dimensional dynamics modeling problems and for complex structural analyses. At JSC, the requested funding will provide for a five-day, one-shift operation for the engineering and development laboratories, such as the electronic Systems Test Laboratory and the Thermal Test Area, in addition to a Class VI computer system. The computer is required to obtain numerical solutions of very large sector matrices for the aerodynamics, thermodynamics and structural mechanics analysis associated with developing and operating manned and robotic space systems.

Data systems and flight support provides a core level of support based on a five-day, two-shift operation of the central computer complex at JSC. Any additional requirements are the responsibility of the benefiting program.

Operations support funding provides for the maintenance of multi-program research and development facilities and equipment, chemical cleaning, engineering design, technical analysis, component fabrication, and logistics support. Examples of specific services to be provided in FY 1990 include: (1) operation and maintenance of specialized electrical and cryogenic systems; (2) operation of shops to do metal refurbishing, anodizing, plating, stripping, and etching of selected hardware; (3) engineering, installation, operation, and maintenance of closed circuit fixed and mobile television required for the support and surveillance of tests; (4) mission imaging services, including audiovisual mission support; (5) fabrication of models, breadboards, and selected items of flight hardware; and (6) technical documentation services. In addition, FY 1990 funds will provide the basic level of collateral support at SSC for continuing main engine testing activities.

In launch systems support, funding provides for the core capability for the engineering, scientific, and technical support at KSC including technical labs and facilities such as the following labs: (1) launch equipment test lab to develop, test and checkout ground support equipment, structures and pyrotechnics; (2) materials science lab for materials testing and malfunction analysis; (3) robotics labs for developing robotic applications for payload preparation and the launch environment; (4) digital electronics lab for testing and evaluating devices and circuits, controls and displays and computer networks. In addition, funding supports several other labs critical to launch support including the instrumentation and hazardous gas lab, fiberoptics/communication lab, software development lab, atmospheric lab, expert systems lab, and the biomedical lab.

PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT

	1989 current estimate	1990 budget request
Payload operations.....	\$49,700,000	\$60,400,000

PAYLOAD OPERATIONS AND SUPPORT EQUIPMENT—CONTINUED

	1989 current estimate	1990 budget request
Payload support equipment.....	15,000,000	20,700,000
Total	64,700,000	81,100,000

The objectives of the Payload Operations and Support Equipment program are to provide payload services, which are required beyond the basic STS standard services for all NASA missions and to provide multi-mission support equipment in support of payload operations. Payload operations provide unique hardware, analyses, and launch site support services to NASA missions. The payload support equipment budget funds the development and acquisition of multi-mission reusable ground support equipment required for a wide range of payloads. This includes test equipment required to checkout payload-to-orbiter interfaces at KSC, mixed cargo hardware such as standard cable harnesses, and displays and controls related to payload bay operations.

Payload operations funding is required to furnish continued payload services for currently scheduled NASA launches. Major NASA payloads receiving support during this year include Hubble Space Telescope (HST), Tracking and Data Relay Satellite (TDRS), Galileo, Ulysses, Space Radar Laboratory (SRL), Space Life Sciences Laboratory (SLS), Upper Atmospheric Research Satellite (UARS), Commercially Developed Space Facility (CDSF), and Gamma Ray Observatory (GRO). Provision also has been made to replace outdated engines on the Super Guppy. In addition, funding is required to initiate technical integration and operations activities to assure compatibility between Shuttle capabilities and Space Station transportation requirements. Initial efforts are included to support development of a standard docking module for the orbiter which would be used by the Space Station and other on-orbit docking requirements. Private sector investment is being pursued for this development.

Payload support equipment estimates reflect the requirement to modify and upgrade selected payload integration facilities for safer, more efficient operations. FY 1990 funding for multi-mission payload support equipment is required for the development, testing and delivery of payload common communication equipment (PCCE) to accommodate required payload data transmission, and initial spares provisioning for Cargo Integration Test Equipment (CITE) and PCCE. Funds for fiber optic cabling and an upgraded operational intercom system in the industrial area at KSC are included in this budget to provide increased reliability and quality of data transmission among cargo facilities. Multi-mission payload support equipment funding also includes orbiter/payload interface hardware for groups of payloads, cargo by cabling, modified aft flight deck panels, and associated display and controls.

ADVANCED PROGRAMS

Advanced programs:	
1989 current estimate.....	\$52,700,000
1990 budget request	48,700,000

The principal objectives of Advanced Program Development are to conduct concept definitions, selected system definition and preliminary design studies, and key advanced developments addressing civil requirements for increased reliability, cost effectiveness, and capability in space flight systems. Information from these studies will support decisions on the best alternatives for developing capabilities required to support future civil mission options. High-leverage advanced development efforts will be conducted to reduce future program development risks and costs through the application of new technology. A complementary objective is to provide an advanced planning programmatic link between the Office of Space Flight and other NASA program offices.

The Advanced Program Development effort is focused on four major areas—advanced transportation, advanced operations support, satellite servicing, and advanced missions. Advanced transportation activities include concept definition of manned launch vehicles and upper stages and systems definition of crew return and cargo vehicles. For manned flight, parallel and complementary studies continue to support Shuttle evolution and to develop the requirements and concepts for a next generation manned vehicle. NASA and DOD continue closely related and coordinated cargo vehicle studies (Shuttle-C and the Advanced Launch System) to define unmanned heavy lift launch vehicles to satisfy both near and long-term mission requirements. The Phase-B preliminary design phase for an assured crew return capability (ACRC) will be initiated in support of the Space Station Freedom. Studies in the upper stages area will include assessment of possible upgrades to the existing Centaur and concept definition of a new, high-performance cryogenic Space Transfer Vehicle to meet advanced missions requirements.

Efforts in advanced operations support systems continue to address advanced operations effectiveness as the key parameter in reducing life-cycle costs for space transportation and orbital systems as well as improving reliability and safety. Innovative operations techniques and approaches are under study and being assessed for improvement of both ground and flight support systems. Advanced development emphasizes demonstration of expert and autonomous systems technologies for current and future space transportation vehicles.

The satellite servicing program focuses primarily on the definition of systems and procedures designed to enhance on-orbit servicing which utilize Shuttle and the planned Orbital Maneuvering Vehicle (OMV) and are planned to be compatible with the Space Station. Studies are under way to define the servicing activities associated with rendezvous and proximity operations from the Shuttle and remote servicing using the OMV. The definition of tankers, couplings, telerobotic servicing aids, techniques and procedures to support on-orbit servicing is also continuing in FY 1989. Transportation-related tether application studies are continuing to define and implement flight experiments and demonstrations including orbital altitude changes without the use of propellants, tether initiated recovery systems for returning small payloads and articles from space, and innovative transportation systems concepts for

automated and manned exploration missions in and beyond Earth orbit.

Advanced mission efforts will continue to focus on potential manned and unmanned missions beyond the Space Station. A major effort to define the orbital debris environment continues in FY 1989 along with studies to investigate ways to minimize debris accumulation and to develop techniques for protection/avoidance procedures for future space orbital systems. The development of the orbital debris radar will be provided under the Space Station program, to begin in FY 1990.

In FY 1990, major emphasis will continue to be placed on concept definition, system definition, and advanced development for advanced transportation, advanced operations, satellite servicing and advanced missions. In the advanced transportation area, studies to define the evolution of manned vehicles, including Space Shuttle improvement and concepts for the next generation manned launch system will be continued. Funding of the ACRC Phase B definition effort will be continued in FY 1990. Definition of the Space Transfer Vehicle will also continue as well as selected advanced development activities in cryogenic storage and transfer, avionics and propulsion.

Advanced operations efforts will emphasize the identification and demonstration of technologies to improve efficiency, flexibility and reliability of current and future space transportation systems. Included in advanced operations is the selective application of expert systems, robotics, automation, and other technologies to labor-intensive and hazardous operations. Launch processing systems, mission control applications, flight planning, training, simulation and other environments will be targeted to demonstrate emerging technologies for improving ground and flight operations.

The satellite servicing area will explore effective manned and unmanned remote servicing concepts. Systems, tools, and techniques will be defined to refuel, repair, and retrieve satellites on a routine basis. Detailed engineering studies will continue to determine the efficiency of future tethered platform applications. Orbital debris studies will also continue to define performance drivers for radar development and operations and to better understand and model the orbital debris environment.

Advanced missions beyond the Space Station will be studied with expanded scope and increased depth. Studies will be conducted to identify potential demands on transportation systems to support agency new initiative planning for human exploration missions (Lunar/Mars).

ADVANCED LAUNCH SYSTEM (ALS)

	1989 current estimate	1990 budget request
Advanced launch systems (civil).....	\$6,500,000	\$5,000,000
Advanced launch systems (propulsion)	74,900,000	
Total	81,400,000	5,000,000

The objective of the joint DOD/NASA Advanced Launch System (ALS) program is to define a new heavy lift launch capability based on advanced technology which will reduce the cost of placing payloads in space. As specified in the ALS management plan, the ALS propulsion advanced development program is led by NASA. Initiated in FY 1987, the ALS propulsion advanced development (Formerly the ALS propulsion focused technology) program focuses on demonstrating the performance and operational capabilities of critical propulsion system components prior to committing to a final design for the flight hardware design and development program. This is an integral element in the joint program which is included in the DOD budget request. In addition, NASA has the funding responsibility to satisfy unique civil requirements not addressed by the joint ALS baseline design. The ALS/Civil studies, initiated in FY 1989, are to refine the definition of civil mission requirements for the ALS program, define civil program requirements for utilization of the ALS, and establish synergism between ALS and civil transportation elements.

The joint DOD/NASA ALS program is the Phase II systems definition stage. Complementary efforts by NASA and DOD are underway to coordinate the ALS Advanced Development activities to most effectively utilize the expertise and facilities of both agencies. These propulsion activities address components and subsystems including combustors, gas generators, turbopumps, control systems components and instrumentation, and health monitoring system components and diagnostic sensors for liquid oxygen/hydrocarbon and liquid oxygen/liquid hydrogen engine systems. Some activity is also being devoted to mid-size solid rocket motor components and combustion technology to support one unique ALS vehicle concept. Consistent with the basic agreement, funding for the NASA activity to meet the joint requirements of this program is included in the DOD budget request.

The ALS/Civil studies will continue with emphasis on the accommodation of advanced missions for human and robotic exploration of the solar system. Inherent in these studies is a series of trades to determine the most effective means of providing services to non-standard spacecraft and payloads. The focus of the studies includes a transportation infrastructure study, payload interface definition, upper stages study, examination of potential booster commonality, and requirements for vehicle man-rating.

TETHERED SATELLITE SYSTEM

Tethered satellite system:

1989 current estimate.....	\$26,400,000
1990 budget request.....	19,900,000

OBJECTIVES AND STATUS

The development of a Tethered Satellite System (TSS) will provide a new reusable facility for conducting space experiments at distances up to 100 kilometers from the Shuttle orbiter while being held in a fixed position relative to the orbiter. A number of significant scientific and engineering objectives can be uniquely undertaken with a TSS facility such as the observation of important at-

mospheric processes occurring within the lower thermosphere, new observations of crustal geomagnetic phenomena, and entirely new electrodynamic experiments interacting with the space plasma. This is being undertaken as a cooperative development program with the Italian government. Formal signing by representatives of both governments of a Memorandum of Understanding took place in March 1984.

The United States is responsible for overall program management, overall systems engineering and integration, orbiter integration, ground and flight operations, development of the deployment mechanism and provision of the non-European instruments (OSSA Funded). The U.S. effort was initiated in 1984. The Italians are responsible for the design and development of the satellite and the European instruments being flown on the joint missions. They initiated their development efforts in 1984.

The FY 1990 funding supports continuation of TSS Development activities consistent with the planned engineering verification flight (TSS-1) in early FY 1991. Current plans call for completion of U.S. hardware assembly in FY 1989 followed by deployer qualification. Integration of the Italian-provided satellite and the deployer-mounted science instruments is now planned to start at KSC in mid-FY 1990, in time to prepare the TSS-1 for flight.

ORBITAL MANEUVERING VEHICLE

Orbital maneuvering vehicle:

1989 current estimate.....	\$73,000,000
1990 budget request	107,000,000

The reusable Orbital Maneuvering Vehicle (OMV) will provide a new STS capability for conducting orbital operations with space craft and payloads beyond the practical operational accessibility limits of the baseline STS. By means of direct man-in-the-loop control, the OMV is being designed to operate as far as 1200 nautical miles altitude above the orbiter. The OMV will provide delivery, maneuvering, and retrieval of satellite payloads to and from altitudes or inclinations beyond the existing STS capability; reboost of satellites to original operational altitudes or higher; delivery of multiple payloads to different orbital altitudes and inclinations in a single flight; and safe deorbit of satellites which have completed their useful life. The OMV is being designed with a limited space-basing capability with the intent of eventually being able to serve the Space Station and to accommodate add-on future "mission kits" needed to support more advanced missions such as the servicing of satellites and platforms and the retrieval of space debris representing an orbital hazard to all future space missions. TRW was competitively selected and is now under contract to develop the OMV. The preliminary design review was held in 1988.

The funds provided in FY 1990 will be used to continue OMV hardware design and development and to finalize OMV specifications required for the critical design review. Critical design review and commencement of hardware fabrication is scheduled for 1990. The flight readiness date for the OMV is FY 1994.

PHYSICS AND ASTRONOMY PROGRAM

FY 1990 BUDGET REQUEST \$894,500,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Hubble space telescope development.....	\$95,900,000	\$67,000,000
Gamma ray observatory development.....	41,900,000	26,700,000
Global geospace science.....	64,400,000	112,300,000
Advanced x-ray astrophysics facility development (AXAF).....	16,000,000	44,000,000
Payload and instrument development.....	81,700,000	71,400,000
Shuttle/Spacelab payload mission management and integration.....	69,700,000	86,100,000
Space station integrated planning and attached pay- loads.....	8,000,000	23,000,000
Explorer development.....	82,100,000	93,200,000
Mission operation and data analysis.....	143,200,00	204,800,000
Research and analysis.....	85,800,000	112,500,000
Suborbital program.....	45,400,000	53,500,000
Total.....	734,100,000	894,500,000

The objectives of the Physics and Astronomy program are to increase our understanding of the origin and evolution of the universe, the fundamental laws of physics, and the formation of stars and planets. Objects studied by the Astrophysics program include distant galaxies and galactic clusters, as well as stars and other structures in nearby galaxies and the interstellar medium in our galaxy. Unusual and exotic phenomena—such as quasars, neutron stars, pulsars and black holes—are of particular interest to the Astrophysics program, and are the target of many ground-based and space-based research programs.

In the Space Physics program, intensive study of our Sun, with its multitude of time-varying phenomena, provides key answers to a vast range of questions requiring comprehensive research into solar-terrestrial processes and the physics and coupling between the solar wind, magnetosphere, ionosphere and atmosphere.

The objectives of the Physics and Astronomy program are accomplished with a mixture of large, complex free-flying space missions, less complex Explorer spacecraft, Shuttle/Spacelab flights and sub-orbital opportunities. In the future, the Space Station will act as a platform for attached payloads and potentially as a servicing point for major free-flying observatories which require assembly, maintenance and refurbishment in orbit. Space-based research allows observations in wavelength regions such as the infrared or the ultra-violet which cannot be carried out on the ground due to the obscuring effects of the atmosphere. Also, observations in the visible light region are vastly improved when conducted above the atmosphere. The entire program rests on a solid basis of supporting research and technology, data analysis, and theory.

Research teams involved in this program are located at universities, industrial laboratories, NASA field centers, and other government laboratories. The scientific information obtained and the technology developed in this program are made available to the sci-

entific communities and the general public for application to the advancement of scientific knowledge, education and technology. The Physics and Astronomy missions undertaken to date have been extraordinarily successful. These include the High Energy Astronomical Observatories (HEAO, 1977-1979), International Ultraviolet Explorer (IUE, 1978), Solar Maximum Mission (SMM, 1980), Active Magnetospheric Particle Trace Explorer (AMPTE, 1984), Dynamics Explorer (DE, 1981), Interplanetary Monitoring Platform (IMP-8, 1972), International Sun-Earth Explorers (ISEE 1 & 2 and ICE, 1977-78), Infrared Astronomy Statellite (IRAS, 1983) and San Marco-D (1988). The IUE, SMM, AMPTE, IMP, DE, and ICE are still operating, and new scientific results are continually emerging from these, as well as from the high quality data sets achieved from the HEAO's, ISEE 1 & 2 and IRAS missions.

The Hubble Space Telescope, scheduled to be launched by the Space Shuttle during FY 1990, will provide an international spaceborne astronomical observatory capable of measuring objects appreciably fainter and more distant than those accessible from the ground, since it will be above the turbulent and absorbent atmosphere. This telescope will be able to resolve spatial features by a factor of ten better than ground-based optical telescopes, and will observe the universe at approximately seven times the distances now possible. This means approximately 350 times the volume of the present universe will be available for study. This increased capability will allow us to address basic questions concerning the origin, evolution, and disposition of galaxies, quasars, clusters, and stars, thus allowing us to significantly increase our understanding of both the early and present universe—its beginning and end.

The Gamma Ray Observatory (GRO) mission will be launched by the Space Shuttle in FY 1990. This mission will measure gamma rays, which are produced by the most energetic and exotic fundamental physical processes occurring in nature. Instruments on this mission will provide unique information on phenomena occurring in quasars, active galaxies, black holes, neutron stars, supernova, and the nature of the mysterious cosmic gamma-ray bursts.

The Global Geospace Science (GGS) program was approved as an FY 1988 new start. It is a complementary science mission to the Collaborative Solar-Terrestrial Research (COSTR) program and enables the U.S. to move from a supporting to a leadership role in solar-terrestrial physics. These projects, collectively referred to as the International Solar-Terrestrial Physics (ISTP) program, are being conducted in cooperation with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). GGS will make the first coordinated geospace measurements in key plasma source and storage regions, with emphasis on the cause-effect relations of energy flow. Together with COSTR, GGS represents research of the highest scientific merit.

The Advanced X-ray Astrophysics Facility (AXAF) was approved as an FY 1989 new start for the x-ray telescope assembly and high resolution mirror assembly. The start of instrument development is planned for FY 1990, with spacecraft development expected in FY 1992. AXAF will be a major national observatory for x-ray astronomy. The 1.2m class grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of 10 increase in angular res-

olution and double the energy coverage which was provided by the Einstein observatory (HEAO-2). It will provide new observations and insights in studies of stellar structure and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies and cosmology. It will restore U.S. leadership in a field pioneered by U.S. astronomers.

Advanced Technology Development activities will continue on the Orbiting Solar Laboratory (OSL), a platform for studies of solar magnetic structures, processes and surface atmosphere, toward a potential new start in the early 1990's. Definition studies of the advanced technology necessary for the Space Infrared Telescope Facility (SIRTF) will continue. SIRTF is intended to measure phenomena associated with the beginning of an evolutionary cycle. This includes cosmic dust, cool interstellar material, star formation, and proto-planetary nebulae in both our galaxy and others.

Since the inception of the U.S. Space program, the Explorer program has been the means for fast-turnaround scientific space missions. The Physics and Astronomy Explorers have been extremely successful. The IUE, a U.S./ESA endeavor, has recently shown that our galaxy has a halo of gas with a temperature of over a million degrees, while the IRAS, a joint U.S./U.K./Netherlands project, has detected and cataloged over 300,000 infrared sources and has shown star formation in other galaxies to be more prevalent than previously thought. IRAS has also demonstrated that at least one quasar has its dominant energy release in the infrared spectral region. Since IRAS completed operations in late 1983, these discoveries have come from analysis of archival data, with many such results expected. ICE, which was designed to provide solar wind data, was redirected in 1985 for the first successful encounter with a comet when it passed through the tail of Comet Giacobini-Zinner, and made Halley's Comet observations in 1986. San Marco-D, a joint NASA/Italian spacecraft, was launched in March 1988. After successfully taking equatorial measurements of the ionosphere, the spacecraft reentered the Earth's atmosphere in December 1988.

Two major Explorer missions are now under development: the Cosmic Background Explorer (COBE) is planned for launch in FY 1989, and the Extreme Ultraviolet Explorer (EUVE) which is scheduled for launch in FY 1992. A third mission, the X-ray Timing Explorer (XTE), is under definition. In addition, a U.S. instrument has been developed for inclusion on the Roentgen Satellite (ROSAT), being built by the Federal Republic of Germany and scheduled for launch in FY 1990. A Cosmic Ray Isotope Experiment (CRIE) has been developed along with a DOD experiment for flight aboard the Combined Release and Radiation Effects Satellite (CRRES), a collaborative mission with DOD and is also scheduled for launch in FY 1990. We are developing an instrument for flight on the Japanese Solar-A mission (previously called the High Energy Solar Physics Mission, HESP). Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. Finally, the Explorer program supports U.S. participation in the Japanese Astro-D Spectroscopic X-ray Observatory mission, to be launched in FY 1993.

The Astrophysics program continues its involvement in the Shuttle/Spacelab program with Astro-1, a set of ultraviolet and soft x-

ray telescope and spectrometers, scheduled for a launch in FY 1990. Astro-1 will investigate the interstellar medium by following up on discoveries made with the IUE. Mission management activities will continue with increasing emphasis on major life sciences and microgravity research missions such as the Spacelab-Life Sciences (SLS), the International Microgravity Laboratory (IML) series and the United States Microgravity Laboratory (USML) series.

Payload and instrument development activities provide the data necessary to conduct basic research projects and to provide correlative and developmental feasibility information for major free-flying spacecraft. Instrument development activities include Shuttle payloads such as the Tether Satellite System (TSS). Also included are Space Plasma Physics flight of opportunity instruments such as those for the Japanese Geotail spacecraft and the European Solar Heliospheric Observer (SOHO) and Cluster spacecraft. This Collaborative Solar Terrestrial Research (COSTR) instrumentation provides the U.S. complement for the European Solar Terrestrial Science Programme (STSP).

The first nearby Supernova since the invention of the telescope appeared in the southern skies in 1987. Since that time, the Physics and Astronomy program has conducted a broad campaign of observations using the Deep Space Network, aircraft, balloons, rockets, and existing spacecraft to take advantage of this unique scientific opportunity.

During the Shuttle recovery period, suborbital observation from balloons, sounding rockets, and high-altitude aircraft have taken on increased significance. This enhanced effort will provide observations and instrument development opportunities for various research groups. Furthermore, increased emphasis will also continue in the Research and Analysis (R&A) and the Mission Operations and Data Analysis (MO&DA) areas in order to maintain a vital research base in Physics and Astronomy.

HUBBLE SPACE TELESCOPE DEVELOPMENT

	1989 current estimate	1990 budget request
Spacecraft	\$84,900,000	\$59,000,000
Experiments	11,000,000	8,000,000
Total	95,900,000	67,000,000

The Hubble Space Telescope (HST) will make a major contribution to understanding the stars and galaxies, the nature and behavior of the gas and dust between them, and the broad question of the origin and scale of the universe. The HST will operate in space above the atmospheric veil surrounding the Earth, increasing dramatically the volume of space accessible for observations. With its significant improvements in resolution and precision in light sensitivity and in wavelength coverage, the HST will permit scientists to conduct investigations that could never be carried out with ground-based observatories limited by the obscuring and distorting effects of the Earth's atmosphere.

The HST will enhance the ability of astronomers to study radiation in the visible and ultraviolet regions of the spectrum. It will be more sensitive than ground-based telescopes and will allow the objects under study to be recorded in greater detail. It will make possible unique observations of objects so remote that the light will have taken many billions of years to reach the Earth. As a result, we will be able to look farther into the distant past of our universe than ever before. The HST will also contribute significantly to the study of the early state of stars and the formation of solar systems, as well as the observation of such highly-evolved objects as supernova remnants and white dwarf stars. With the HST, we may be able to determine the nature of quasars and the processes by which they emit such enormous amounts of energy; it may also be possible to determine whether some nearby stars have planetary systems.

The HST is scheduled to be delivered into orbit by the Space Shuttle in December 1989. Data from its scientific instruments will be transmitted to Earth via the Tracking and Data Relay Satellite System. The HST is designed for on-orbit maintenance and repair.

During FY 1988, the HST program continued at a reduced level of activity. The schedule for launch and operations was adjusted as a result of changes of the STS manifest. HST program activity focused on corrections to a few cases of off-nominal systems performance observed in the intensive period of testing in late FY 1986. This included rework of some components and instruments, improvements to the power system, and adjustments to the thermal control system. In addition to this work on the HST spacecraft, the planned tests of the ground system continued, building toward final operational capability on the stretched-out launch schedule. Work also continued on preparing for the future on-orbit servicing of HST spacecraft. A logistics system was put in place, and development was underway on advanced scientific instruments and other components for orbital replacement. Astronauts conducted realistic training with the replacement components, using specially-developed tools.

Planning for FY 1989 reflects the added delays in the STS launch schedule. After a pre-ship functional test verifies the readiness of the HST spacecraft for shipment, it will enter a period of inactive storage. Assuming a successful flight test of the modified C5-A transport plane, the spacecraft will be flown to Kennedy Space Center in the summer 1989 for final launch preparations. Ground system verification and buildup to full operational capability will continue, consistent with the extended launch schedule.

The FY 1990 funding level is required to complete those program activities that were delayed because of adjustments to the STS launch schedule. These activities include pre-ship preparation of the spacecraft, shipment to the Kennedy Space Center, launch preparations and launch operations at Kennedy, and the initial phases of orbital operations. In addition, the requested funding level will support the buildup of the HST ground system to the level required for sustained science operations.

GAMMA RAY OBSERVATORY DEVELOPMENT

	1989 current estimate	1990 budget request
Spacecraft	\$32,300,000	\$21,500,000
Experiments and ground operations.....	9,600,000	5,200,000
Total	41,900,000	26,700,000

The Gamma Ray Observatory (GRO) will study the highest energy electromagnetic radiation emitted from sources in the cosmos. This spectral region represents one of the last frontiers in astronomy to be studied at high sensitivity. Because of their extreme energy, gamma-rays are produced by the most energetic and intriguing phenomena occurring in the universe: phenomena occurring in the central energy source region of quasars, in supernovae, near black holes, and on the surface of neutron stars. Gamma-rays provide the unique direct signature of all nuclear processes which occur in astrophysics: the synthesis of elements, cosmic rays interacting in the interstellar medium, and transformations involving the fundamental particles of physics. GRO will provide new information on phenomena ranging from the enigmatic, and yet unidentified, cosmic gamma-ray bursts, to the diffuse gamma-ray sky background, whose origin must have cosmological significance.

The GRO science and instrumentation rests on a foundation of exploratory investigations and developments from previous spacecraft, such as the Small Astronomy Satellite-2 (SAS-2, 1972), the High Energy Astronomical Observatories (HEAO's 1 and 3, 1977 and 1979), and the European COS-B (1975). A community of astronomers and physicists has built up both the data analysis experience and developed the theoretical concepts to complete the infrastructure required for a successful space mission. Participation in the GRO mission includes the university science community as well as government and industry. International involvement, with a complete Principal Investigator team based in Europe, is extensive.

Due to the low flux of cosmic gamma-rays, their penetrating nature, and the high background produced by cosmic-ray interactions, detailed observations require large instruments to be flown in space for extended periods of time. The four complementary instruments selected for GRO represent a quantum jump in sensitivity, spectral range, and spectral, spatial, and temporal resolution over any previous missions or instruments in these energy ranges. GRO, scheduled for launch on the Space Shuttle in 1990, is designed to be pointed at fixed directions in space for hours or weeks to obtain the long exposures required.

In FY 1988, the modal survey and static structural loads tests were completed and all spacecraft subsystems for GRO were delivered. In FY 1989, all instruments will be delivered to TRW and integrated with the GRO spacecraft which will then undergo functional and environmental observatory testing.

FY 1990 funding is required to ship the spacecraft from TRW to Kennedy Space Center, to support launch preparations, to launch GRO in April 1990, and to support post-launch checkout.

GLOBAL GEOSPACE SCIENCE

	1989 current estimate	1990 budget request
Global geospace science	\$64,400,000	\$112,300,000
STS operations.....	(5,300,000)	(10,100,000)

Global Geospace Science (GGS) will be part of the United States' contribution to the International Solar Terrestrial Physics (ISTP) program. This program is an international, multi-spacecraft, collaborative science mission designed to provide the measurements necessary for a new and comprehensive understanding of the interaction between the Sun and the Earth.

GGS is a complementary science mission to the Collaborative Solar Terrestrial Research (COSTR) program which provides instruments and launch support to gain science return in a cooperative effort with the European Space Agency (ESA) and the Japanese Institute of Space and Aeronautical Science (ISAS). The scientific value of this effort will be greatly enhanced by the addition of the two GGS spacecraft. The combined program will include five spacecraft missions: two U.S. spacecraft, Wind and Polar; two ESA spacecraft, SOHO and Cluster; and one ISAS spacecraft, Geotail.

The GGS mission will measure and model the effects of the Sun on the Earth's space system to enhance our understanding of the processes and flow of energy and matter in the solar energy chain from outer geospace to atmospheric deposition. GGS will also enhance our ability to assess the importance of variations in atmospheric energy deposition from the geospace system to the terrestrial environment. GGS consists of two fully-instrumented U.S. spacecraft, Wind and Polar, making simultaneous measurements in key geospace regions. Instruments and theory investigations were selected through an Announcement of Opportunity to U.S. and foreign investigators. GGS provides the first coordinated geospace measurements in key plasma source and storage regions, multi-spectral global auroral imaging, and multi-point study of magnetospheric response to solar wind. Wind and Polar are planned for launch in FY 1993.

Essentially all commitments by foreign governments are in place and development activities have commenced. Spacecraft contract award is planned for the second quarter of FY 1989, as is final confirmation and initiation of instrument development activity. GGS allows the United States to serve as a full partner in the ISTP program, reinforcing our commitments to international cooperation and maintaining a leadership role in solar-terrestrial physics.

Definition studies are complete and FY 1990 funds are required to continue development of the GGS spacecraft, instruments and ground system. FY 1990 funding will allow continuation of these early development efforts in order to take advantage of simultaneous measurements provided by the COSTR program and other solar-terrestrial research efforts.

ADVANCED X-RAY ASTROPHYSICS FACILITY DEVELOPMENT

	1989 current estimate	1990 budget request
Mirror development.....	\$16,000,000	\$35,000,000
Experiments.....		9,000,000
Total	16,000,000	44,000,000

The Advanced X-ray Astrophysics Facility (AXAF) is the next major initiative in x-ray astronomy and is the third of the four Great Observatories. AXAF will provide new observations and insights in studies of stellar structures and evolution, large-scale galactic phenomena, active galaxies, clusters of galaxies, and cosmology. The 1.2 meter grazing incidence telescope will provide a factor of 100 increase in sensitivity, a factor of ten increase in angular resolution, double the energy coverage which was provided by the Einstein Observatory (HEAO-2), and will address fundamental questions of modern astrophysics. Timely development of the AXAF program is required in order to fly in concert with the Hubble Space Telescope, which will observe the universe in visible and ultraviolet radiation, and the Gamma Ray Observatory, which will conduct observations in the gamma ray spectrum. The scientific return of these "Great Observatories" will be enhanced enormously if flown together to observe the whole range of phenomena in the cosmos, from the most tranquil to the most violent, and provide a complete physical picture of the universe's most enigmatic objects.

AXAF will be a long-lived observatory designed for on-orbit instrument replacement and servicing. Between the Shuttle, and Space Station Freedom, the U.S. will have the unique capability to maintain this telescope in orbit. During 1988, Phase 2 of the Technology Mirror Assembly (TMA) was completed and TRW was selected as the prime contractor. Starting in FY 1989, Congress has implemented a phased implementation approach to the program. Development funding in the FY 1989-1991 timeframe has been reduced, limiting nearterm development activities to the High Resolution Mirror Assembly/X-ray Telescope Assembly (HRMA/XTA) and the science instruments. Funding was also provided in Research and Analysis under Advanced Technology Development (ATD) to support other activities such as observatory definition, long-lead parts procurements and design studies leading to anticipated full-scale initiation of observatory development in FY 1992. This has resulted in a 6-month delay in launch readiness from December 1995 to June 1996.

FY 1990 funding continues activities on the HRMA/XTA, with particular emphasis on completion of the largest and most challenging set of parabolic/hyperbolic mirrors (P1/H1). Science instrument development will be initiated during FY 1990.

PAYLOAD AND INSTRUMENT DEVELOPMENT

	1989 current estimate	1990 budget request
Collaborative solar terrestrial research	\$43,900,000	\$54,800,000
Tether satellite systems	7,700,000	6,200,000
Shuttle test of relativity experiment (BP-B)	17,900,000	
Astrophysics payloads	9,600,000	7,200,000
Space physics payloads	2,600,000	3,200,000
Total	81,700,000	71,400,000

Instrument development activities support a wide range of instrumentation—from early test, checkout and design of instruments for long-duration free-flying missions to international flights of opportunity. The Collaborative Solar Terrestrial Research Program (COSTR) will provide state-of-the-art instrumentation for flight opportunities on international spacecraft and various U.S. spacecraft of opportunity. Emphasis is on developing scientific instruments conceived through the Space Physics Research and Analysis and Sounding Rocket programs. Instruments to be developed in the near term will provide a U.S. contribution to an international thrust in space physics research in the 1989-1995 timeframe, principally, the European Solar Terrestrial Science Programme (STSP) and the Japanese Geotail Mission.

The Tether Satellite System (TSS), scheduled for launch in FY 1991, will provide a facility for conducting experiments weighing 500 kg or less from distances of 100 km above or below the Space Shuttle. The objective of the initial TSS mission (TSS-1) is to verify the controlled deployment, retrieval and on-station stabilization of a satellite tethered from the Space Shuttle orbiter, and to carry out an electrodynamics experiment using a conducting tether extended 20 km above the orbiter, TSS-1 is an international cooperative project with the Italian government. The U.S. is responsible for overall project management, system integration, developing the tether deployment and retrieval system, developing and integrating U.S.-provided instruments, and flight on the Shuttle. Italy is developing the satellite and is responsible for development and integration of Italian-provided instruments.

Astrophysics and Space Physics Payloads include a number of instruments designed for flight on the STS and ELV's. Emphasis will be on instrument development for study of the complex relationships of solar irradiance and the near-Earth plasma environment (Atmospheric Laboratory for Applications and Science—ATLAS), and the diffuse x-ray background and spectra of point and extended sources (Shuttle High Energy Astrophysics Lab—SHEAL).

The Shuttle test flight of the Gravity Probe-B instrument involves the development of a multigyroscope experimentation package to fly as an attached payload on the Shuttle in 1993, as an integral part of the study of relativity. Due to the constraints placed on the agency's FY 1990 budget and the limited growth possibilities for future years, OSSA plans to terminate ongoing efforts in this program after FY 1989.

In FY 1990, the COSTR program will continue development of U.S.-provided instruments for the ISAS/NASA Geotail mission which will explore the Earth's magnetosphere and deep geotail region. NASA will also be developing U.S.-provided instruments and mission support equipment for the ESA/NASA joint Cluster and SOHO missions, which will provide unique capabilities for measurement of solar oscillations and solar corona. Funding is also required to continue development of U.S.-provided instruments and for core equipment development and integration on TSS-1. Funding will also continue to support the development of Astro-1 and SHEAL-2 payloads which will fly in FY 1990 and FY 1992 respectively. In addition, alternate launch opportunities will be sought for applicable payloads.

SHUTTLE/SPACELAB/PAYLOAD MISSION MANAGEMENT AND INTEGRATION

Shuttle/Spacelab payload mission management and integration:

1989 current estimate.....	\$69,700,000
1990 budget estimate.....	86,100,000

The primary objective of the Spacelab Payload Mission Management program is to manage the mission planning, integration, and execution of all NASA Spacelab and attached Shuttle payloads. This includes system management and engineering development of flight support equipment and software; development of certain interface hardware; payload specialist training and support; integration of the science payloads with the Spacelab system; payload flight operations; and data dissemination to experimenters.

Mission management activities are continuing for Physics and Astronomy missions including the Astro-1 mission and the Shuttle High Energy Astrophysics Lab (SHEAL). Astro-1 is scheduled for flight in FY 1990; SHEAL is currently planned for flight in FY 1992. The primary instrument on SHEAL, the Broad-Band X-ray Telescope (BBXRT) is also under accelerated development to accommodate an earlier flight of the Astro mission, in order to make timely observations of the Supernova 1987a.

Mission management activities are continuing on several other space science and applications missions, such as the Atmospheric Laboratory for Applications and Science (ATLAS). The first of this series is planned for flight in 1990. The mission will incorporate a large number of instruments designed to study the complex relationships of solar irradiance, atmospheric composition and changes, and the near-earth plasma environment. Other missions include flight of an imaging radar in the early 1990's; a series of Spacelab Life Sciences missions (SLS), the first scheduled for launch in June 1990; a joint microgravity mission with the Japanese (SL-J); a series of cooperative International Microgravity Laboratories (IML's); and flight of the ongoing series of Materials Science Laboratories (MSL's) and U.S. Microgravity Laboratories (USML's). Currently under consideration is a United States Microgravity Payload (USMP) series, which will incorporate and expand the MSL missions in order to maximize materials processing capabilities in space. Mission management activities also support other (non-OSSA) payloads. For example, the Space Station heat pipe ad-

vanced radiator element experiment payload will test a heat rejection system with high potential for future spaceborne applications.

Mission management activities will escalate in FY 1990 as Spacelab missions resume with the flight of Astro-1 in FY 1990. Integration, testing, and evaluation will continue for other major Shuttle/Spacelab missions including SHEAL-2, the ATLAS series, the Spacelab Life Science (SLS) missions, the International Microgravity Laboratories (IML), as well as a new German Spacelab follow-on. In addition, alternate launch opportunities will be sought for applicable payloads.

SPACE STATION INTEGRATION PLANNING AND ATTACHED PAYLOADS

Space station integration planning and attached payloads:

1989 current estimate.....	\$8,000,000
1990 budget estimate.....	23,000,000

The primary objective of the Space Station Integration Planning and Attached Payloads program is to provide the necessary planning, definition and development of payloads and missions as the Office of Space Science and Applications prepares for future uses of the Space Station complex. This includes the definition of attached payloads suitable for deployment on the early Space Station, as well as the definition of integration and operational requirements, in anticipation of the new, integrated methods of conducting scientific research which the Space Station will offer.

Studies continue to define the end-to-end science operations requirement for the Space Station era (i.e., the cycle from identification of science requirements, through mission planning and operations to dissemination, analysis and archiving of data). Studies also continue to determine the best use of Space Station resources (such as, power, crew time, volume, data handling capabilities, pointing capabilities) in terms of science requirements. Potential attached payloads have been identified for further feasibility and definition and appropriate studies are underway; Announcements of Opportunity selections for Attached Payloads will be issued in FY 1989.

In FY 1990, definition and development will continue on those attached payloads selected for early flight on the Space Station. In addition, an augmentation of \$5 million has been added to support mission management activities such as operations support and accommodations and requirements analysis. This augmentation will also include study and analysis of Space Station Information Systems integration.

EXPLORER DEVELOPMENT

	1989 current estimate	1990 budget request
Cosmic background explorer	\$10,600,000	
Extreme ultraviolet explorer	41,400,000	\$45,800,000
Roentgen satellite experiments	3,700,000	1,700,000
Combined release and radiation effects satellite experiments	2,200,000	2,200,000
Solar-A	4,600,000	3,200,000

EXPLORER DEVELOPMENT—CONTINUED

	1989 current estimate	1990 budget request
Other explorers.....	19,600,000	40,300,000
Total	82,100,000	93,200,000

Investigations selected for Explorers are usually of an exploratory or survey nature, or have specific objectives not requiring the capabilities of a major observatory. Past Explorers have discovered radiation trapped within the Earth's magnetic field, investigated the solar wind and its interaction with the Earth, studied upper atmosphere dynamics and chemistry, mapped our galaxy in radio waves and gamma-rays, and determined the properties of the interstellar medium through ultraviolet observations. Recent Explorers have performed active plasma experiments on the magnetosphere, made in-situ measurements of the comet Giacobini-Zinner, and completed the first high sensitivity, all-sky survey in the infrared, discovering over 300,000 sources.

Explorers under development will study the properties of the cosmic microwave background, which is important for understanding the early universe and cosmology, survey the sky in the extreme ultraviolet for the first-time, and measure time-variable phenomena in x-ray sources. The Explorer program also provides a means of developing instruments for "payload-of-opportunity" missions, such as those involving other Federal agencies or international collaboration.

The San Marco-D mission, a cooperative project with Italy, was launched in March 1988 on a Scout expendable launch vehicle to study the relationship between solar activity and meteorological phenomena on the Earth. After successfully completing its mission objective, the spacecraft reentered the Earth's atmosphere in December 1988. The Cosmic-Ray Isotope Experiment (CRIE) will be included in the Combined Release and Radiation Effects Satellite (CRRES), a joint NASA/DOD mission, now scheduled for an Atlas-Centaur launch to a geosynchronous transfer orbit (GTO) in FY 1990. The CRRES GTO mission will also release trace chemicals, whose transport in the magnetosphere can be observed from ground and airborne-based instruments.

Current plans call for the launch of the Cosmic Background Explorer (COBE) in FY 1989. COBE will carry out a definitive, all-sky exploration of the infrared background radiation of the universe between the wavelengths of one micrometer and 9.6 millimeters.

In FY 1989, development continues on the Extreme Ultraviolet Explorer (EUVE), and on the x-ray imaging instrument to be flown on the German Roentgen Satellite (ROSAT). EUVE, scheduled for launch on a Delta ELV in FY 1991, will carry out the first detailed all-sky survey of extreme ultraviolet radiation between 100 and 900 angstroms. ROSAT, a cooperative project between the Federal Republic of Germany (FRG) and the United States will perform a high resolution imaging survey of the x-ray sky and provide in-depth studies on selected objects. The U.S. will provide one of the ROSAT instruments and the launch services; Germany will provide

the spacecraft, telescope, and other instruments. Current plans call for ROSAT to be launched on a Delta ELV also in FY 1990.

In FY 1986, a new cooperative mission called Solar-A was initiated with the Japanese. Solar-A will be launched in FY 1991 to study the Sun during the upcoming solar maximum. The U.S. has selected an instrument for this spacecraft, which will relate energetic solar phenomena and dynamic coronal structures seen in hard and soft x-rays to the topology of evolving solar magnetic fields. This will allow the first simultaneous observations of these phenomena from space.

Definition and design will continue in FY 1989 on the X-ray Timing Explorer (XTE). This mission can be ready for launch as early as FY 1994. During FY 1986, a "Dear Colleague" letter was issued to obtain proposals for future Explorers. Over 43 were received and four candidate missions—the Advanced Composition Explorer (ACE), Far Ultraviolet Spectroscopy Explorer (FUSE), Mesosphere/Lower Thermosphere Explorer (MELTER) and the Nuclear Astrophysics Explorer (NAE)—were selected for further definition.

In addition to the traditional Delta-class explorers, the Explorer program will begin development of "small class" explorers. While subject to more stringent constraints than Delta-class missions (weight, telemetry, power, etc.), it is anticipated that a significant number of scientifically exciting missions can utilize this capability and be developed on a short timescale. Following a peer review of proposals, it is anticipated that several small-class missions will be selected for development with the initial one being launched as early as FY 1991. In addition, alternate launch opportunities will be sought for applicable payloads.

During FY 1990, development activity will continue on EUVE and on instruments scheduled to fly on CRRES, ROSAT, Solar-A, Astro-D and the first small-class explorer mission. Development activities will also begin on XTE.

MISSION OPERATIONS AND DATA ANALYSIS

[Dollars in thousands]

	1989		1990 budget request
	Budget estimate	Current estimate	
Hubble space telescope operations.....	\$59,100		
Hubble space telescope maintenance and refurbishment.....	52,200		
Hubble space telescope operations and servicing.....		\$88,500	\$113,200
Hubble space telescope data analysis.....		9,800	21,200
Astrophysics mission operations and data analysis.....	29,300	33,300	54,500
Space physics mission operations and data analysis.....	15,600	11,600	15,900
Total.....	156,200	143,200	204,800

The purpose of the Mission Operations and Data Analysis (MO&DA) effort is to conduct operations and analyze data received from physics and astronomy spacecraft after launch. The program

also supports the operation of a number of spacecraft after their originally planned objectives have been achieved, for purposes of conducting specific investigations that have continuing high scientific significance. The funding supports the data analysis activities of the many investigators at universities and other research organizations associated with astrophysics and space physics operational satellite projects. Actual satellite operations, including control centers and related data reduction and engineering support activities, are typically carried out under a variety of mission support or center support contracts.

Space Physics research activities rely on data received from the Interplanetary Monitoring Platform (IMP), the Active Magnetospheric Particle Trace Explorer (AMPTE), the Dynamics Explorer (DE) which are still operational, and the International Sun Earth Explorers (ISEE-1&2) which reentered the Earth's atmosphere in October 1987. IMP continues to provide the only available source of solar wind input measurements to the Earth. IMP, along with ISEE-1 & 2, DE, AMPTE, and the Swedish Viking satellite successfully conducted a multisatellite campaign called Polar Regions and Outer Magnetospheric International Study (PROMIS) in 1986. The ISEE-3 spacecraft, renamed the International Cometary Explorer (ICE), provided complementary solar wind measurements upstream of Comet Haley in 1986, and was retargeted for a return to Earth orbit in 2014 for retrieval and presentation to the National Air and Space Museum (NASM).

In addition to the normal support required for mission operations, the Hubble Space Telescope (HST) program encompasses several unique aspects which must be provided for in advance of the launch. The HST is designed to operate for more than a decade, using the Space Shuttle/Orbital Maneuvering Vehicle combination and/or Space Station for on-orbit maintenance of the spacecraft and in-orbit changeout or repair of the scientific instruments. In order to reduce the likely servicing requirements of the HST, development was initiated on Nickel-Hydrogen batteries and Back Surface Field Reflecting Solar array to improve the power lifetime on the spacecraft.

The HST will be used primarily by observers selected on the basis of proposals submitted in response to periodic solicitations. Science operations will be carried out through the independent HST Science Institute. The Institute operates under a long-term contract with NASA. While NASA retains operational responsibility for the observatory, the Institute implements NASA policies in the area of planning, management, and scheduling of the scientific operations of the HST.

Initiation of the definition and implementation of a unified data system which will ensure the fullest access and exploitation of the various mission data sets, with emphasis on the wealth of data to be returned by the Great Observatories, will be undertaken. An initial definition process involving extensive inputs from the astrophysics community has now been completed, and FY 1989 funding in the MO&DA program will enable the principal elements of this essential system to be put in place.

The FY 199 funding level is required to maintain critical skills for the operation and maintenance of the Hubble Space Telescope, and to prepare for launch activities in FY 1990.

The FY 1990 budget will also support initial mission operations and data analysis for the Gamma Ray Observatory, scheduled for launch in FY 1990, the Cosmic Background Explorer (COBE), scheduled for launch in FY 1989 and ROSAT, also scheduled for launch in FY 1990.

Mission operations, data analysis, and guest investigator programs will continue for the Solar Maximum Mission (SMM), the Interplanetary Monitoring Platform (IMP), the Dynamics Explorer (DE), the Active Magnetospheric Particle Trace Explorer (AMPTE), International Cometary Explorer (ICE), and the International Ultraviolet Explorer (IUE). The High Energy Astronomical Observatories (HEAO 1-3), International Sun-Earth Explorers 1 and 2 (ISEE-1 & 2), and the Infrared Astronomy Satellite (IRAS) data analysis will also continue. These programs have produced valuable data sets which are used by a wide segment of the science community. FY 1990 funds will also be used to continue development of the unified astrophysics data system.

RESEARCH AND ANALYSIS

	1989 current estimate	1990 budget request
Supporting research and technology	\$85,800,000	\$101,500,000
Advanced technology development		11,000,000
Total	85,800,000	112,500,000

This program provides for the preliminary studies required to define missions and/or payload requirements, as well as providing a research and technology base necessary to define, plan and support flight projects.

Supporting Research and Technology (SR&T)

The objectives of supporting research and technology are to: (1) optimize the return expected from future missions through scientific problem definition, development of advanced instrumentation and concepts, and sound definition of proposed new missions; (2) enhance the value of current space missions by carrying out complementary and supplementary ground-based observations and laboratory experiments; (3) develop theories to explain observed phenomena and predict new ones; (4) strengthen the technological base for sensor and instrumentation development and conduct the basic research necessary to understand astrophysics phenomena and solar-terrestrial relationships; and, (5) continue the acquisition, analysis and evaluation of data from laboratories, balloons, rocket and spacecraft activities.

Research is supported in the disciplines of astronomy; astrophysics; and gravitational, plasma, cosmic ray and solar physics. Research in astronomy and astrophysics involves the study of stars, galaxies, interstellar and intergalactic matter, and cosmic rays. Space physics research and analysis is a broadly structured effort

to enhance our understanding of the characteristics and behavior of plasmas in the solar corona, the interplanetary medium and in the vicinity of the Earth and other planets. Theory activities are related to all the Physics and Astronomy disciplines and are critical to the correlation of available information. The development of new instruments, laboratory and theoretical studies of basic physical processes, and observations by ground-based and balloon-borne instruments will also be continued. Results achieved in the SR&T program will have a direct bearing on future flight programs. For example, the development of advanced x-ray, ultraviolet, and infrared astronomy imaging devices under this program may enable spacecraft to carry instruments for astronomical observations which have increased orders of magnitude in sensitivity and improved resolution over currently available detectors.

One major thrust of the space physics program is directed at studies of the near-Earth geospace environment, from the flow of the solar wind past the magnetosphere, to variations in the plasma environment detectable near the surface of the Earth. Not only are these studies of great interest for basic plasma physics but there are also many practical ramifications, such as ionospheric influences on communication, global circulation of the atmosphere driven by magnetospheric input, the charging of spacecraft immersed in plasma, and the behavior of antennas and their signals in the magnetosphere.

The SR&T program carries out its objectives through universities, nonprofit and industrial research institutions, NASA centers and other government agencies. Current emphasis is being placed on studies of advanced instrumentation with increased sensitivity and resolution.

Advanced Technological Development (ATD)

The Advanced Technological Development (ATD) activities support detailed planning and definition of potential new physics and astronomy missions. ATD activities assure that future missions address the scientific questions most important to the evolution of knowledge in the field, and that those missions use the appropriate technology and techniques. FY 1989 activities continue the study of a Stratospheric Observatory For Infrared Astronomy (SOFIA) as potential follow-on for the C-141 in the 1990s. SOFIA would incorporate a 3-meter class infrared telescope mounted in a suitable aircraft.

During FY 1990, the supporting research and technology program will support those tasks which contribute to maintaining a firm base for viable physics and astronomy and space physics programs. FY 1990 funding will support continued studies on potential future missions. In the data analysis activities to be carried out at a university and government research centers in FY 1990, emphasis will be placed on correlative studies involving data acquired from several sources (spacecraft, balloons, sounding rockets, research aircraft and ground observatories). ATD funding will support the AXAF observatory definition, long-lead procurements and design studies at the mission contractor, TRW, Inc., leading to anticipated full-scale initiation of observatory development in FY 1992.

SUBORBITAL PROGRAM

	1989 current estimate	1990 budget request
Sounding rockets	\$27,000,000	\$30,500,000
Airborne science and applications	9,800,000	10,900,000
Balloon program	8,600,000	12,100,000
Total	45,400,000	53,500,000

The suborbital program uses balloons, aircraft, and sounding rockets to conduct versatile, relatively low-cost research of the Earth's ionosphere and magnetosphere, space plasma physics, stellar astronomy, solar astronomy, and high energy astrophysics. Activities are conducted on both a national and international cooperative basis.

Sounding rockets

A major objective of the sounding rocket program is to support a coordinated research effort. Sounding rockets are uniquely suited for performing low altitude measurements (between balloon and spacecraft altitude) and for measuring vertical variations of many atmospheric parameters. Special areas of study supported by the sounding rocket program include the nature, characteristics, and composition of the magnetosphere and near space; the effects of incoming energetic particles and solar radiation on the magnetosphere, including the production of aurorae and the coupling of energy into the atmosphere; and the nature, characteristics, and spectra of radiation of the Sun, stars and other celestial objects. Also included is support for NASA's final Spartan mission, Spartan 201, which consists of a 17-inch diameter solar telescope with an ultraviolet coronagraph and a white light coronagraph to measure the intensity and scattering properties of solar light. Spartan 201 is planned for Shuttle launch in the early 1990s.

Additionally, the sounding rocket program provides several OSSA programs with the means for flight testing instruments being developed for future flight missions. The program also provides a means for calibrating flight instruments and obtaining vertical atmospheric profiles to complement data obtained from orbiting spacecraft. Approximately forty rockets are scheduled for launch in FY 1989.

Airborne science and applications

Research with instrumented jet aircraft has been an integral part of the NASA physics and astronomy program since 1965. For astronomy research, the airborne science and applications program operates the Kuiper Airborne Observatory (KAO). This full-scale manned facility consists of a C-151 aircraft equipped with a 91 centimeter infrared telescope. The C-141's ability to fly for several hours at altitudes approaching 13 kilometers provides a cloud-free site for astronomical observations above most of the infrared-absorbing water vapor in the Earth's atmosphere. This has been essential in expanding astronomical observations into the infrared

region of the electromagnetic spectrum from one micrometer to hundreds of micrometers.

In FY 1988, the C-141 conducted two major campaigns in the southern hemisphere to study Supernova SN1987a. The C-141 played a critical role in the continual effort to characterize the Supernova by measuring its velocity, morphology and composition. During 1988, the C-141 also conducted studies of the Sun's upper atmosphere and observed a stellar occultation by the planet Pluto which provided the first experimental evidence of the existence of an atmosphere on that planet. Other observations included the exploration of star-forming regions and other areas in our own galaxy and solar system. In FY 1989, 72 missions are planned, including support of the SN1987a campaign with additional flights in the southern hemisphere.

Balloon program

The Balloon provides a cost-effective means to test flight instrumentation in the space radiation environment and for making observations at altitudes which are above most of the water vapor in the atmosphere. Balloon experimentation is particularly useful when studying infrared, gamma-ray, and cosmic-ray astronomy. In many instances it is necessary, because of size, weight, cost, or lack of other opportunities, to fly primary scientific experiments on balloons. In addition to the level-of-effort science observations program, significant emphasis has been and will be placed on development of a balloon capable of lifting more than 3,500 pounds, and to support missions lasting several days.

The Balloon program funding is required for purchase of balloons, helium, launch services, tracking and recovery, as well as for maintenance and operations of the National Scientific Balloon Facility (NSBF) at Palestine, Texas and remote launch sites. Funding for the experiments flown on balloons is provided from other research and technology programs supporting the various scientific disciplines.

FY 1990 funds will provide for continuation of the sounding rocket, Spartan, and balloon programs including management and operation of the NSBF. This funding is also required to continue definition activities for balloon improvement and long-duration balloon flights. In FY 1990, the Airborne Science and Applications funding will be used to continue flights of the KAO. In addition, alternate launch opportunities will be sought for applicable payloads.

SPACE LIFE SCIENCES PROGRAM

FY 1990 BUDGET REQUEST \$124,200,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Human space flight and systems engineering	\$27,600,000	\$42,800,000
Space biological sciences	10,100,000	27,600,000
Life sciences flight experiments		

	1989 current estimate	1990 budget request
Research and analysis	40,400,000	53,800,000
Total	78,100,000	124,200,000

The goals of the Space Life Sciences program are to advance knowledge in all areas of space life sciences and to develop medical and biological systems which enable human habitation in space. Results from the research program are applied to: the immediate needs of maintaining astronaut health and productivity; understanding the response of biological mechanisms to weightlessness; the design of controlled ecological life support systems; understanding the origin, evolution and distribution of life in the universe; and, understanding the biosphere of the planet Earth.

Continuing support of the Space Life Sciences program is essential to: understand the basic biological mechanisms of gravitational responsivity; evolve the critical technologies necessary to enable long-term piloted space flight; and, develop the capability to sustain a permanent manned presence in space. The research program includes ground-based and space research efforts which are mutually supportive and integrated, and the study of fundamental biological processes and space-related medical problems through a variety of disciplines and techniques.

The Space Life Sciences research and analysis program includes five major elements: 1) space medicine, which addresses the health and well-being of space crews by seeking to understand and prevent adverse physiological changes which occur in space flight and upon return to Earth; 2) space biology, an integrated basic science research program that studies the fundamental mechanisms of gravitational interaction with all orders of plants and animals in flight and ground experiments; 3) controlled ecological life support systems, a program of research and critical technology development for life support systems necessary to maintain life in space autonomously for long periods of time; 4) exobiology research, which is directed toward understanding the origin and distribution of life and life-related molecules on Earth and throughout the universe; and, 5) biospheric research, which explores the interaction between life on Earth and its physical and chemical environment.

The Space Life Sciences flight program, provides scientific and engineering support to select, define, develop, conduct and report on in-space experiments, and data analysis of medical biological investigations involving humans, animals and plants. The flight program is actively preparing experiments for launch on Spacelab missions in FY 1990 and FY 1991. Definition activities are underway to develop payloads for later Spacelab missions and early Space Station utilization. An international cooperative program, the U.S./U.S.S.R. working group in space biology and medicine, pursue investigations of joint interest.

Beginning in FY 1989 the Life Sciences flight experiments program has been restructured into two categories: human space flight and systems engineering, and space biological sciences. The major focus of the human space flight and systems engineering program is to ensure effective Shuttle and Space Station crew performance. The space biological space program will pursue the basic plant,

animal, and human research necessary to support a broad based space biology program including those areas of research which are essential to the human space flight and systems engineering program.

SPACE LIFE SCIENCES FLIGHT PROGRAM

	1989 current estimate	1990 budget request
Human space flight and systems engineering	\$27,600,000	\$42,800,000
Space biological sciences	10,100,000	27,600,000
Life sciences flight experiments		
Total	37,700,000	70,400,000

The objective of the Space Life Sciences flight program is to assimilate information and scientific questions from various life science disciplines and develop payloads designed to expand the understanding of the basic physiological mechanisms involved in adaptation of weightlessness. The program includes selection, definition, in-flight execution, data analysis and reporting on medical and biological investigations involving humans, animals and plants. Human space flight and systems engineering activities further NASA's ability to extend the duration, enhance the performance, and improve the safety of human space flight. Past experience indicates that humans clearly undergo physiological changes during weightlessness. Many of the observed changes are physiologically significant and are not well understood. Shuttle/Spacelab and Space Station missions are suitable for gaining a greater understanding of the basic mechanisms underlying this response to weightlessness. Space Biological Sciences flight activities use the space environment, especially weightlessness, to further basic understanding of fundamental biological processes. Such flight experiments lead to a firmer comprehension of the underlying mechanisms of gravitational adaptation, enhance our basic science knowledge, make it possible to improve the management of several existing problems, and increase the confidence with which we can estimate the physiological consequences of more sustained weightless exposure and design corresponding countermeasures. Another key area of research in space biological sciences is exobiology.

The human space flight and systems engineering and space biological sciences programs are included in the resumption of Life Sciences Space Transportation Systems (STS) missions starting in FY 1990. The FY 1990 budget supports the increase in flight program activity.

In FY 1990 funding is required for the final preparation and flight of approved experiments on the first dedicated Life Science mission (Spacelab Life Sciences-1 (SLS-1)) which is scheduled to be launched in June 1990 and will concentrate on studies of human and animal biomedical responses, with emphasis on cardiovascular, bone metabolism and vestibular functions. SLS-1 will be unique in several respects: it will be the first Shuttle/Spacelab mission dedicated entirely to life sciences, and it will involve highly skilled scientists as payload specialists, thus permitting the use of numerous

experimental techniques and procedures never before utilized in space. Many of the experiments and associated flight hardware flown on earlier Shuttle flights will support and enhance preparations for SLS-1 and subsequent missions.

Final preparations are also underway to support the flight of the first International Microgravity Laboratory (IML-1) mission in 1991. Approximately 50 percent of the payload relates to space life sciences, with the U.S. focus on plants, neurovestibular studies, human performance, radiation and cellular differentiation.

Efforts will continue on definition and development of new experiments (selected through the Announcement of Opportunity (AO) process) and hardware that will be flown on future Spacelab/Shuttle missions in FY 1991 and 1992—i.e., Shuttle mid-decks, the Japanese SL-J mission, the second dedicated life sciences missions (SLS-2), the German D-2 mission, IML-2 and SLS-3. Collaboration with the Soviet Union on its COSMOS biosatellite program will continue with joint research planned on COSMOS flights in 1989 and 1991. Phase B studies continue on the reusable reentry satellite (RRS) for life sciences research, and NASA is coordinating development of the RRS with several international partners.

In FY 1990, under the Human Space Flight and Systems Engineering programs, efforts will continue in a major new area of research—ensuring effective Shuttle crew performance on-orbit and during landing on extended duration orbiter missions. Investigations will proceed on Spacelab and middeck experiments with the operational goal of enabling long duration missions in time for the U.S. Microgravity Lab-1 mission planned for 1992. Research efforts will also be focused on extending operational tours of duty of flight crews on the Space Station in order to achieve greater cost-effectiveness. This program is required to meet the four to five yearly Shuttle flights assumed in the Space Station baseline program. It will also allow more effective use of human resources by developing countermeasures that maintain crew health and productivity and minimize impact on in-flight crew time. Crew debility and rehabilitation time following long duration space flight will also be reduced. Spacelab opportunities will be used to conduct supporting experiments and fly associated payloads. Preparation for the Space Station will commence with investigation planning, technology assessment for flight experiment, and critical technology and hardware development.

In FY 1990, under the Space Biological Sciences program, the detailed definition and development phase will begin on an integrated centrifuge facility for Spacelab that will support a broad spectrum of life sciences research using small animals and plants. For the first time, it will provide continuous on-board 1-G control that can separate influences of weightlessness from other effects of space flight. It will allow scientists to test the response of living organisms to operational forces at various stages of adaption to weightlessness. The centrifuge will be developed on Spacelab where in-flight engineering verifications for the centrifuge, associated equipment and logistical support will be performed. The Spacelab centrifuge will provide a testbed for subsequent development of a Space Station Centrifuge. This facility represents a market enhancement of basic research capability for the Life Sciences program.

In FY 1990, studies will be conducted in the Space Biological Sciences Program to determine how space biology research will be accommodated on the Space Station, as well as to define instrument and facility requirements. Studies will identify unique scientific and hardware transition requirements from continuing Spacelab flights into Space Station freedom operations. In addition, technology assessment, advanced technology development, hardware definition, and experiment definition and planning will be conducted.

RESEARCH AND ANALYSIS

Space life sciences research and analysis:

1989 Current estimate.....	\$40,400,000
1990 budget request.....	53,800,000

The research and analysis activity supports Space Life Sciences program goals of: advancing knowledge in all areas of space life sciences and developing medical and biological systems which enable human habitation in space. The program is composed of five elements: (1) space medicine; (2) space biology; (3) controlled ecological life support systems research; (4) exobiology; and, (5) biospheric research.

The Space Medicine program is responsible for assuring the physical welfare, performance and adequate treatment of in-flight illness or injuries of spaceflight crews. Such conditions as space motion sickness, spatial disorientation, fluid shifts and endocrine changes, can decrease performance and cardiovascular tolerance and possibly aggravate latent disease. These conditions must be carefully evaluated to determine preventative measures. To this end, careful medical selection, periodic evaluation of health status, and in-flight monitoring of the adaptation to space and success of physiological countermeasures will be continually undertaken. In addition, long-term monitoring of space flight crews will be performed in a standardized fashion in order to identify risk factors and establish the long-term clinical significance associated with repeated exposure to the space environment. Biomedical research will investigate the fundamental physiological basis for problems encountered in manned spaceflight. Research areas include: clinical medicine; neuroscience; cardiopulmonary, musculoskeletal, and regulatory physiology; cell and developmental biology; behavior, performance and human factors; and, radiation and environmental factors.

The Space Biology program explores the role of gravity in life processes and uses gravity variations as an environmental tool to investigate fundamental biological questions. Specific objectives are to perform the basis science research required to identify and investigate: 1) the role of gravity in plant and animal behavior, morphology, development and physiology; 2) the mechanisms of gravity sensing and the transmission of this information within both plants and animals; 3) the interactive effects of gravity and other stimuli (e.g., light) and stresses (e.g., vibration and disorientation) on the physiology of organisms; 4) the uses of gravity to study the normal nature and properties of living organisms; and, 5) the effects of microgravity to facilitate plant and animal growth, long-term survival and reproduction in space.

The Controlled Ecological Life Support Systems program seeks to provide air, water and food to support life through bioregenerative closed systems which receive only energy from the external environment. Development of such systems is a critical path element for long duration manned spaceflight and lunar colonization.

The Exobiology program is directed toward understanding the origin and evolution of life, and life-related molecules, on Earth and throughout the universe. Research seeks to trace the pathways leading from the origin of the universe through the major epochs in the evolution of living systems. Research encompasses: the cosmic evolution of the biogenic compounds, prebiotic evolution, early evolution of life, and evolution of advanced life. Emphasis is placed on understanding these processes in the context of the planetary and astrophysical environments in which they occurred. Flight experiments in Earth orbit and on planetary missions are important program elements. Theoretical and laboratory investigations are also included in this program to develop a better understanding of the conditions on Earth as related to early chemical and biological evolution.

The Biospheric Research program explores the interaction between global biological and planetary processes to develop an understanding of global biogeochemical cycles. Laboratory and field investigations are correlated with remote sensing data to characterize the influence of biological processes in global dynamics. Biospheric modeling efforts integrate biological data with atmospheric, climate, oceanic, terrestrial, and biogeochemical cycling data to reflect the state of the biosphere as a function of both natural and anthropogenic perturbations.

In addition to conducting its own research and analysis program, the Office of Space Science and Applications collaborates with the Office of Aeronautics and Space Technology on the Project Pathfinder. Pathfinder supports research of critical path elements for long-term manned missions in order to inform policy makers of the requirements (as well as uncertainties, risks and technological issues) involved in such efforts as a lunar base or manned Mars mission. Life science research is directed to the Humans-in-Space element of Project Pathfinder and focuses on the areas of human performance, extravehicular activity and life support. Critical areas of investigation in human performance include: biomedical requirements for artificial gravity; advanced medical care technology for remote locations; radiation protection; and psychological and habitability factors affecting crew behavior and performance on long duration missions. Research in extravehicular activity focuses on: developing requirements for portable life support systems and habitability of space suits; and gathering the anthropometric and bioengineering data needed to develop pressurized suit gloves that allow adequate manual dexterity. The Life Support program develops and tests technologies that will provide the capability for closed-loop life support. Important factors include waste processing, food production, air revitalization, and water purification.

The Space Medicine program will collect information on occupational exposure in microgravity on each Shuttle flight and conduct in-flight clinical testing of countermeasures, especially in the area of vestibular dysfunction, cardiovascular deconditioning and mus-

cular atrophy. Resolving problems associated with the initial adaptation to weightlessness such as space motion sickness and fluid shifts will continue to be of high priority. Research emphasis will be placed on operational management of space adaptation syndrome. Approaches such as autogenic (biofeedback) techniques will be evaluated in flight to provide a basis for development of specific countermeasures. Research will commence in the field of biomechanics. Understanding the dynamics of bodily adaptation to physical forces and being able to measure stress on the human body is crucial to designing countermeasures to maintain astronaut health and productivity. Research in the fields of psychology and the ergonomics of man/machine interface will be supported for their importance in improving the performance and efficiency of flight crews. Research in radiation biology will continue because it is necessary to precisely measure dosages and the effects of cosmic and solar radiation in order to determine the optimum radiation shielding required for humans in space. Research is in progress to develop pressurized space suits for quick reaction situations and to develop corresponding pressurized suit gloves.

In conjunction with NASA's development of the Extended Duration Orbiter and the Space Station, the Space Medicine program will support extended crew time in space with extensive research in the physiological changes associated with longer exposures to weightlessness. Bone demineralization, muscle atrophy, neurovestibular disturbances and cardiovascular deconditioning will be studied in ground-based simulation so appropriate countermeasures can be designed. This accelerated program of directed research, bed rest studies and protocol development and evaluation will allow more effective use of human resources in space by developing physiological countermeasures that minimize impact on in-flight crew time. Critical technology requirements will be addressed and research focused on implementation initiated.

The Space Biology program will concentrate ground research on: developing working models of functioning gravity-sensing neural (information) networks to understand neurosensory processing in microgravity; understanding the physiological side effects of centrifugation in preparation for use of the Shuttle-Space Station centrifuge as a research tool; and identifying the cellular events of the gravity perception mechanism in plants. Research in preparation for flight opportunities on the Shuttle and the Soviet biosatellite COSMOS will focus on genetic, cytological, developmental and metabolic effects of gravity on plants and animals. Fundamental research in gravitational response mechanisms in plant and animal development will be developed in preparation for future biosatellite and Space Station experiments.

The Controlled Ecological Life Support Systems program will continue to investigate basic biological processes and physical methods to control the interior environment of manned spacecraft. In developing such a life support system, the near term emphasis will be on system definition and development of design concept and critical technologies for flight, and supporting research in the areas of controlled-environment plant production, waste processing and human nutrition.

The Exobiology program will emphasize the development of new flight experiment concepts to investigate models of early Solar System evolution and mechanisms for the synthesis of biologically significant molecules in space. The program will further develop analytic capabilities to utilize an expanding extraterrestrial sample base, participate in the retrieval of samples, and focus science on emerging opportunities in planetary exploration. In FY 1990, definition and design phases will be completed in the program's microwave observing project which will analyze microwave signals in space for evidence of advanced life elsewhere in the galaxy. Funds will be used to begin the development phase of signal processing systems which will be used with existing radio astronomy facilities and NASA's Deep Space Network antennas.

The Biospheric Research program will place emphasis on improving estimation techniques for determining the structural state of the terrestrial biomass by combining ground-based measurements at tropical, temperate, and wetland sites with remote sensing data and biogeochemical modeling of the interactions of ecosystems on a global scale. Information gathered through remote sensing will also be used to help nations prepare for outbreaks of vector-borne disease (malaria) by allowing predictive modeling of the occurrence of the disease vector (mosquitoes).

In FY 1990, Specialized Centers of Research (SCOR) will be established at universities to support long-term, broad-based interdisciplinary research on selected high priority research topics. The SCOR program, which is modeled on the highly successful National Institutes of Health program, will help increase science results by concentrating resources, facilities and personnel on focused research problems. SCORs will conduct research in the following science programs: biomedical, operational medicine, space biology, exobiology, biospherics, and controlled ecological life support systems.

PLANETARY EXPLORATION PROGRAM

FY 1990 BUDGET REQUEST \$396,900,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Galileo development	\$73,400,000	\$17,400,000
Magellan	43,100	
Ulysses.....	10,300	14,500
Mars observer	102,200	100,500
Comet rendezvous asteroid flyby/Cassini		30,000
Mission operations and data analysis.....	110,700	155,400
Research and analysis	76,900	79,100
Total	416,600,000	396,900,000

The Planetary Exploration program encompasses the scientific exploration of the solar system including the planets and their satellites, comets and asteroids, and the interplanetary medium. The program objectives are: (1) to determine the nature of planets, comets, and asteroids as a means for understanding the origin and evolution of the solar system; (2) to better understand the Earth

through comparative studies with the other planets; (3) to understand how the appearance of life in the solar system is related to the chemical history of the solar system; and, (4) to provide a scientific basis for the future use of resources available in near-Earth space. Projects undertaken in the past have been highly successful based on a strategy that places a balanced emphasis on the Earth-like inner planets, the giant gaseous outer planets, and the smaller bodies (comets and asteroids). Missions to these bodies start at the level of reconnaissance to achieve a fundamental characterization of the bodies, and then proceed to levels of more detailed study.

The reconnaissance phase of inner planet exploration, which began in the 1960's, is now virtually completed, although we still know little about the nature of the planet Venus' surface. Mars has provided program focus because of its potential as a site of biological activity. The Viking landings in 1976 carried the exploration of Mars forward to a high level of scientific and technological achievement, thereby setting the stage for the next step of detailed study. Analyses of meteorites and the lunar rock samples returned by Apollo continue to be highly productive, producing new insights into the early history of the inner solar system and thus leading to a revision of our previous theoretical concepts. The Pioneer Venus mission is continuing to carry the study of the Earth's nearest planetary neighbor and closest planetary analog beyond the reconnaissance stage to the point where we have now obtained a basic characterization of Venus' thick, massive atmosphere, as well as fundamental data about the formation of the planet.

The exploration of the giant outer planets began more recently. The Pioneer-10 and -11 missions to Jupiter in 1973 and 1974 were followed by the Voyager-1 and -2 spacecraft encounters in 1979. Voyager-1 then encountered Saturn in November 1980, and Voyager-2 in August 1981. The Voyager data on these planets, their satellites, and their rings have revolutionized our concepts about the formation and evolution of the solar system. Voyager-2 encountered Uranus in January 1986 and has provided our first look at this giant outer planet. Its trajectory is now carrying it to an encounter with the planet Neptune in August 1989. The Pioneer-10 and 11 and Voyager-1 spacecraft are on trajectories heading out of the solar system, as they continue to return scientific data about the outer reaches of the solar system.

Galileo will be launched on a Shuttle/Inertial Upper Stage (IUS) combination in October 1989 on a trajectory using gravity assists at Venus and Earth. The comprehensive science payload will extend our knowledge of Jupiter and its system of satellites well beyond the profound discoveries of the Voyager and Pioneer missions. During twenty-two months of operation in the Jovian system, Galileo will inject an instrumented probe into Jupiter's atmosphere to make direct analyses, while the orbiter will have the capability to make as many as ten close encounters with the Galilean satellites.

Ulysses is a joint NASA and European Space Agency (ESA) activity. The mission will carry a package of experiments to investigate the Sun at high solar latitudes that cannot be studied from the Earth's orbit. Ulysses will be launched in October 1990 using the Shuttle and IUS/PAM-S launch stages.

Magellan will provide global maps of the cloud-shrouded surface of Venus, including its land forms and geological features. Using a synthetic aperture radar to penetrate the planet's opaque atmosphere, Magellan will achieve a resolution sufficient to identify small-scale features and to address fundamental questions about the origin and evolution of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's gravity field as well as internal stresses and density variations so that the evolutionary history of Venus can be compared with that of the Earth. Magellan is scheduled for launch in April 1989 from the Shuttle with an IUS.

Mars Observer will follow up on the earlier discoveries of Mars by Mariner 9 and Viking and will emphasize the geologic and climatic evolution of this complex planet. The mission will utilize a modified Earth-orbiting spacecraft, thereby benefiting from previously developed technology. Mars Observer will be launched in September 1992, using the Titan III/TOS launch stages.

In FY 1990, development will begin on the Comet Rendezvous Asteroid Flyby (CRAF) and Cassini (the Saturn Orbiter/Titan Probe) missions for launches in August 1995 and April 1996, respectively. Both missions will provide new understanding on the origin of the solar system and may provide new clues to the origin of life as well.

Beginning in late 1985, we entered an exciting new phase of exploration by making our first close-up studies of the solar system's mysterious small bodies—comets and asteroids. These objects may represent unaltered original solar system material, preserved from the geological and chemical changes that have taken place in small planetary bodies. By sampling and studying comets and asteroids, we can begin to make vigorous inquiries into the origin of the solar system itself. These efforts began with the encounter of Comet Giacobini-Zinner by the International Comet Explorer (ICE) spacecraft in September 1985 and continued through our involvement with the 1986 encounters and observations of Comet Halley by U.S. and foreign spacecraft and by intensive studies of the comet from ground-based observatories coordinated through the International Halley Watch. Continued observations, studies of existing data and the archival of these data sets are ongoing.

Research and analysis activities will continue to maximize the scientific return from current missions and from such Earth-based activities as lunar sample and meteorite analysis, telescope observations, theoretical and laboratory studies, and instrument definition. This program strives for interdisciplinary coordination among various research groups and for the wide dissemination of scientific results. A close association is also maintained between the research programs and planning activities to define the scientific rationale and technology needed for future missions. The program also supports the growing involvement of U.S. scientists as participants on foreign-sponsored missions.

GALILEO DEVELOPMENT

	1989 current estimate	1990 budget request
Spacecraft	\$34,880,000	\$6,200,000
Experiments	13,670,000	3,300,000
Ground operations	24,850,000	7,900,000
Total	73,400,000	17,400,000
Mission operations and data analysis		(39,200,000)

The objective of the Galileo program is to conduct a comprehensive exploration of Jupiter, its atmosphere, magnetosphere, and satellites through the use of both remote sensing by an orbiter and *in-situ* measurements by an atmospheric probe. The scientific objectives of the mission are based on recommendations by the National Academy of Sciences to provide continuity, balance, and orderly progression of the exploration of the solar system.

The orbiter and probe will be launched together in October 1989 as a combined payload using a Shuttle/Inertial Upper Stage (IUS) combination on an initial trajectory toward Venus, followed by two Earth swingbys. The three gravitational assists will provide the energy required for a trajectory to Jupiter not otherwise obtainable with this launch vehicle. When the orbiter arrives at Jupiter it will provide remote sensing of the probe entry site and provide the link for relaying the probe data back to Earth. Twenty-two months of orbital operations will follow during which Jupiter's dynamic magnetosphere and two major satellites will be extensively mapped. During this time ten close flybys of Jupiter's four major satellites are targeted.

The Galileo flight system will be powered by two general purpose heat-source Radioisotope Thermoelectric Generators (RTG) developed by the Department of Energy. The orbiter will carry approximately 100 kg of scientific instruments and the probe will carry approximately 25 kg of scientific instruments. During FY 1989, the spacecraft system test will be completed prior to shipment to Kennedy Space Center for integration with the IUS and Shuttle. Mission operations software development and testing will also continue in preparation for launch and post-launch operations.

FY 1990 funds will provide for completion of integration of the spacecraft with the IUS and Shuttle in preparation for launch in October 1989 and post-launch characterization of the spacecraft.

MAGELLAN DEVELOPMENT

1989 current requests:

Spacecraft	\$23,430,000
Experiments	5,880,000
Ground operations	13,790,000
Total	43,100,000
Mission operations and data analysis	(17,100,000)
Space transportation system operations	(52,600,000)

The objective of the Magellan mission is to address fundamental questions regarding the origin and evolution of Venus through global radar imagery of the planet. Magellan will also obtain altimetry and gravity data to accurately determine the planet's topography and gravity field as well as internal stresses and density variations. The detailed surface morphology of Venus will be analyzed to compare the evolutionary history of Venus with that of the Earth.

The Magellan spacecraft will carry a single major scientific instrument, a synthetic aperture radar, which will be used to obtain high resolution images of the planetary surface as well as altimetric data. Gravity data will be obtained by processing radio signals from the spacecraft. Spacecraft development has made extensive use of existing designs, technology, and residual hardware. For example, the spacecraft uses an existing bus structure, large antenna, and propulsion components from the Voyager program.

In April 1989, the Magellan spacecraft will be launched by the Shuttle/Inertial Upper Stage (IUS) on a trajectory to Venus. Arriving at Venus in August 1990, the spacecraft will map a major portion of the planet over a 243 day period (one Venus year) with a ground resolution of about 150 meters. During FY 1989, both the spacecraft and the radar sensor were shipped to the Kennedy Space Center (KSC), where they are being assembled into the spacecraft flight configuration and completing final testing. Subsequently, the spacecraft will be integrated with the IUS and the Shuttle in preparation for launch in April 1989.

ULYSSES DEVELOPMENT

	1989 current estimate	1990 budget request
Spacecraft.....	\$4,230,000	\$5,600,000
Experiments.....	3,885,000	3,500,000
Ground operations.....	2,185,000	5,400,000
Total.....	10,300,000	14,500,000
Space transportation system operations.....	(32,900,000)	(90,100,000)

Ulysses is a joint mission of NASA and the European Space Agency (ESA). ESA is providing the spacecraft and some scientific instrumentation. The United States is providing the remaining scientific instrumentation, the launch vehicle and support, tracking support, and the Radioisotope Thermoelectric Generator (RTG). The mission is designed to obtain the first view of the Sun above and below the plane in which the planets orbit the Sun. The mission will study the relationship between the Sun and its magnetic field and particle emissions (solar wind and cosmic rays) as a function of solar latitude, to provide a better understanding of solar activity on the Earth's weather and climate.

Ulysses was restructured in FY 1981 from a two-spacecraft mission—one provided by the United States and one provided by ESA—to a single ESA spacecraft mission. However, the United States' participation in the program remains substantial. NASA is

responsible for five of the nine principal investigator instruments, and three of the four European investigations have U.S. co-investigators.

The Ulysses launch is planned for October 1990, using the Shuttle and IUS/PAM-S launch stages. During 1989, support to ESA is continuing to make the spacecraft compatible with the new upper stage configuration. Launch approval activities involving the RTG, and support for retesting the spacecraft and the science instruments are also continuing.

FY 1990 funding will support launch approval activities for the RTGs in preparation for launch in October 1990. Periodic testing of the science instruments will also continue.

MARS OBSERVER DEVELOPMENT

	1989 current estimate	1990 budget request
Spacecraft	\$60,605,000	\$61,000,000
Experiments	36,095,000	30,900,000
Ground operations	5,500,000	8,600,000
Total	102,200,000	100,500,000
Space transportation system operations	(5,000,000) ¹	(44,700,000)

The Mars Observer mission is the first in a series of planetary observer missions utilizing a lower cost approach to inner solar system exploration. This approach, which was recommended by NASA's Solar System Exploration Committee, starts with a well-defined and focused set of science objectives and uses modified production-line Earth-orbital spacecraft and instruments with previous space flight heritage. The objectives of the Mars Observer mission are to extend and complement the data acquired by the Mariner and Viking missions by mapping the global surface composition, atmospheric structure and circulation, topography, figure, gravity and magnetic fields of Mars to determine the location of volatile reservoirs and observe their interaction with the Martian environment over all four seasons of the Martian year.

Mars Observer will be launched in September 1992 on a Titan III with a Transfer Orbit Stage (TOS). The spacecraft will be inserted into a near-polar Martian orbit in 1993, from which it will carry out geochemical, geophysical, and climatological mapping of the planet over a period of approximately one Martian year, which is about two Earth-years.

FY 1989 funding is providing for completion of detailed design and initial fabrication of the instrument hardware and for continuation of system design of the overall mission. Detail design of the spacecraft, and parts and subassembly procurements will continue.

FY 1990 funding will support the completion of spacecraft and instrument final designs. Initial hardware fabrication for both the spacecraft and instruments will also begin.

COMET RENDEZVOUS ASTEROID FLYBY (CRAF)/CASSINI DEVELOPMENT

1990 budget request:

Spacecraft	\$19,800,000
Experiments	8,100,000
Ground operations	2,100,000
Total	30,000,000

During the 1970's, our Nation established scientific and technological leadership in scientific exploration of the outer solar system. The CRAF/Cassini program will extend our nation's presence in important ways during this critical period in solar system science. CRAF will be launched in August 1995, fly closely past the asteroid Hamburga in 1998, and rendezvous and with the Comet Kopff in 2000 for two years of intense study. During this period, CRAF will deliver a penetrator to study, for the first time, the interior composition of a comet nucleus. Cassini will be launched in April 1996, fly past the asteroid in Maja in 1997, gain gravity-assist velocity from Jupiter in the year 2000 while observing this planet, and arrive at Saturn in 2002 for four years of study of the Saturnian system. After achieving an orbit around Saturn, Cassini will eject a probe through the atmosphere of Saturn's moon Titan, measure atmospheric composition, and gain the first images of Titan's surface. The orbiting spacecraft will use radar to map most of Titan's surface.

The CRAF/Cassini program, building upon the discoveries made by the Pioneers and Voyagers spacecraft, will provide unprecedented information on the origin and evolution of our solar system and will help tell how the necessary building blocks for the chemical evolution of life are formed elsewhere in the universe. CRAF/Cassini targets (comet, Titan, Saturn system) have a common origin in the outer solar system. The icy conditions on all the small bodies preserve a record of different stages and processes that occurred during solar system formation and evolution. CRAF will provide the first long-term study of a comet, its active nucleus, and the nature and behavior of its ejected gases. It will enable direct analysis of the best-preserved primordial solar system material, possibly including interstellar matter. Thus it may be possible to assess organic molecules present at the beginning of the solar system and their potential contributions to the origin of life. Cassi will provide intensive, long-term observations of Saturn's atmosphere, rings, magnetosphere, and moons. The Cassini probe will conduct direct physical and chemical analyses of Titan's organically rich, nitrogen atmosphere, which is a possible model for the pre-biotic stage of Earth's atmosphere. Thus through the joint study of origins with CRAF and early processes with Cassini, using data from each in support of the other, the CRAF/Cassini program will help establish the early evolutionary processes of our solar system.

Both CRAF and Cassini will use virtually identical Mariner Mark II spacecraft and hence common design, fabrication, test, and integration team elements. This commonality significantly reduces the overall cost of design and development. With contributions from the Department of Defense and NASA's Space Research and Technology program, some \$100 million has been invested in pre-project definition of the Mariner Mark II spacecraft system and in

demonstrating required advanced technologies. Science instruments for CRAF have been tentatively selected, and mission design issues for both missions are well understood. Therefore, NASA is confident of technical readiness to proceed.

The CRAF/Cassini program has strong components of international cooperation. The Federal Republic of Germany has agreed to provide the spacecraft propulsion system and one science instrument for CRAF and may do the same for Cassini. The European Space Agency (ESA) has selected the Cassini probe as its major new science program for this year at an estimated total cost of about \$200 million. Furthermore, ESA member states will contribute about \$75 million worth of science instruments and scientist participation. These contributions are tentative, however, pending approval of CRAF/Cassini for a FY 1990 new start.

FY 1990 funding is required to initiate development and long lead procurement activities of the CRAF and Cassini spacecraft in order to achieve an August 1995 launch to the comet Kopff and an April 1996 launch to Saturn. A selection of the tentative science instrument payload for the CRAF mission has been made and development will proceed in FY 1990. Science instrument development will also be initiated for Cassini investigations selected through the NASA Announcement of Opportunity process planned for December 1989.

MISSION OPERATIONS AND DATA ANALYSIS

	1989 current estimate	1990 budget request
Galileo operations		\$39,200,000
Magellan operations	\$17,100,000	37,800,000
Voyager extended mission	2,300,000	
Pioneer programs	8,300,000	9,800,000
Voyager/Neptune mission	40,124,000	9,300,000
Voyager interstellar mission		15,000,000
Planetary flight support	42,876,000	44,300,000
Total	110,700,000	155,400,000

The objectives of the mission operations and data analysis activities are in-flight operation of planetary spacecraft and the analysis of data from these missions. Currently, two major classes of planetary spacecraft are operating—the Pioneer and the Voyager spacecraft. The planetary flight support activities are those associated with the design and development of planetary flight operation systems, and other activities that support the mission control, tracking, telemetry, and command functions for all planetary spacecraft.

The two Voyager spacecraft are now exploring the outer solar system on trajectories that will take them into interstellar space. Voyager 1 continues to provide data on the interplanetary medium in that distant part of the solar system. In January 1986, Voyager 2 made a close flyby of the planet Uranus, the first time this planet has ever been visited by a spacecraft. During this flyby, it made detailed observations of the planet, its rings, and moons. Upon completion of the Uranus encounter, the spacecraft began its

path to the planet Neptune, where, in August 1989, it will provide us with our first close look at this distant planet.

After the Neptune encounter, Voyager 2, designated as the Voyager Interstellar Mission (VIM), will be on a trajectory which will extend exploration beyond the outer limits of the Sun's sphere of influence. The principal objectives of the VIM are to investigate and characterize the outer Solar System particles and fields environment and interstellar media, to provide data on the location of the heliopause in conjunction with Pioneer-10 and -11, and to continue the successful Voyager program of ultraviolet astronomy.

Pioneers 10 and 11 continue to explore the outermost solar system. Pioneer 10 will soon enter the unexplored region beyond Pluto where the Sun's influence is secondary to those of true interstellar space. These spacecraft will continue the search for gravitational evidence of a tenth planet. Pioneers 6-9 are still collecting information on the interplanetary magnetic field and solar wind as they orbit the Sun. The Pioneer Venus orbiter continues to obtain data on Venus' atmosphere and magnetosphere and its interaction with the solar wind. In late 1985, the spacecraft's spin axis was adjusted to allow ultraviolet observations of Comet Halley. Pioneer Venus was the only spacecraft able to observe the Comet at its closest approach to the Sun, thus providing critical enhancements to the data gathered by foreign spacecraft.

The planetary flight support activities include the procurement, operation and maintenance of mission operations and general purpose scientific and engineering computing capabilities at the Jet Propulsion Laboratory (JPL). In addition, the activity supports the development of the Space Flight Operations Center (SFOC) at JPL. This facility will be a versatile, cost-effective means for carrying out multimission data acquisition, telemetry, image processing, and for commanding of planetary and orbital spacecraft.

FY 1989 funding is providing support for the Voyager and Pioneer operations, for analysis of scientific data returned by these missions, and for the extension of the Voyager 2 mission to ao 1989 encounter with the planet Neptune. Activities are also continuing in multimission support development and software designs for activities. FY 1989 funding will also support initial operations for the Magellan mission, which will be launched in April 1989.

FY 1990 funding is required for the continued operation and data analysis activities in support of the Pioneer and Magellan missions as well as for Voyager on its interstellar trajectory. Operations activities are beginning for the Galileo mission, which will be launched in October 1989. Development activities will also continue on the Space Flight Operations Center (SFOC) at the Jet Propulsion Laboratory.

RESEARCH AND ANALYSIS

	1989 current estimate	1990 budget request
Supporting research and technology	\$46,250,000	\$61,300,000
Advanced programs	24,700,000	12,300,000
Mars data analysis	4,750,000	4,500,000

RESEARCH AND ANALYSIS—CONTINUED

	1989 current estimate	1990 budget request
Halley's comet co-investigations and watch.....	1,200,000	1,000,000
Total	76,900,000	79,100,000

The research and analysis program consists of four elements required to: (1) assure that data and samples returned from flight missions are fully exploited; (2) undertake complementary laboratory and theoretical efforts; (3) define science rationale and develop required technology to undertake future planetary missions; and (4) coordinate an International Halley's Comet Watch program.

The supporting research and technology activity includes planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, and U.S. scientist participation on foreign missions.

The planetary astronomy activity includes all observations made by ground-based telescopes of solar system bodies, excluding the Sun. Emphasis is on the outermost planets, comets and asteroids. Observations are made at a wide range of wavelengths from ultraviolet to radio. The rate of new discoveries continues to be high, and the data acquired is used both for basic research in support of planetary program objectives and for direct support of specific flight missions. The planetary astronomy funding also provides for the continued operation of the Infrared Telescope Facility in Hawaii. The planetary atmospheres activity includes data analysis, laboratory, and theoretical efforts. The properties of other planetary atmospheres are amenable to measurement with planetary spacecraft and can aid us in better understanding our own weather and climate. Observations of the atmospheres of Venus, Jupiter and Saturn, acquired by Pioneer Venus and Voyager, have laid the basic observational groundwork for major advances in this field.

The planetary geology/geophysics activity is a broadly scoped program that includes the study of surface processes, structure, and history of solid components (including rings) of the solar system and investigation of the interior properties and processes of all solar system bodies, both solid and gaseous. This program emphasizes comparative studies to gain a fundamental understanding of the physical processes and laws which control the development and evolution of all planetary bodies, including the Earth. In this respect, data from the Magellan mission will be of crucial importance.

The planetary materials/geochemistry activity supports an active scientific effort to determine the chemistry, mineral composition, age, physical properties and other characteristics of solid material in the solar system through the study of returned lunar samples and meteorites and through laboratory and theoretical studies of appropriate geochemical problems. Extraterrestrial dust grains, collected for analysis, continue to yield new and otherwise unobtainable information about the solar system and its early history. This program is coordinated with lunar sample and meteorite research, which is supported by other agencies such as the Nation-

al Science Foundation. The operation of the Lunar Curatorial Facility is also supported by this activity.

The instrument definition activity is directed toward ensuring maximum scientific return from future missions by the definition and development of state-of-the-art scientific instrumentation, which are optimized for such missions.

The support for U.S. science investigators on foreign missions currently is being provided for U.S. participation on the USSR Phobos missions.

The objective of the advanced program activity is to provide planning and preparation for the systematic exploration of the solar system on a scientifically and technically sound basis. Prospective planetary missions are identified and defined through long-range studies; the technological and fiscal feasibility is evaluated, and the scientific merit is determined through interaction with the scientific community. The strategy for future solar system exploration has been developed by the Solar System Exploration Committee (SSEC), an advisory group, which has recommended a comprehensive program of missions to the inner and outer solar system. The Mars Data Analysis program continues to support analysis of data obtained by Viking and earlier missions so that we are scientifically prepared for the next phase of Mars exploration. It also supports the establishment of a Planetary Data System (PDS) which will permit the archiving of these and all other data products in a manner which will promote and facilitate their use.

The International Halley's Comet Watch program is part of an international program of cooperative astronomical observations of Halley's Comet. During 1986 and 1987, support was provided to nearly three dozen U.S. co-investigators on the European Space Agency's (ESA) Giotto mission, and to conducting complementary remote sensing investigations carried out with ground-based telescopes, aircraft, rockets, and distant spacecraft. Concurrently, an observation program called the International Halley's Comet Watch, coordinated by the United States, conducted world-wide scientific observations of the Comet Halley. The objectives of the Watch are: (1) to coordinate scientific observations of Comet Halley through its 1985-1986 apparition; (2) to promote the use of standardized instrumentation and observing techniques; (3) to help ensure that data is properly documented and archived; and (4) to receive and distribute data to participating scientists. Activities in FY 1988 were directed toward analyzing and archiving data. These activities will continue in 1989 at a reduced level of support.

During FY 1990, research efforts will continue in the areas of planetary astronomy, planetary atmospheres, planetary geology/geophysics, planetary materials/geochemistry, instrument definition, Mars data analysis, and in the development of required technology to undertake future missions. Ground telescope observations will provide data complementary to that obtained from the flight missions, with emphasis on the outermost planets, comets and asteroids. Beginning in FY 1990, funding will also support the upgrading and modernization of ground-based laboratory instrumentation in order to reduce maintenance costs and down time and to improve capabilities. Initial efforts will be directed towards upgrading the Arecibo Radar facility. A variety of efforts will be pursued

to improve our understanding of planetary atmospheres, including laboratory studies of reactions in deep planetary and tenuous cometary atmospheres. Geology/geophysics research will be directed at specific problems in understanding the various processes that have shaped planetary surfaces, as well as geological analyses and a cartography effort based on the Galilean, Saturnian and Uranian satellite imaging data acquired by Voyager.

Analysis of lunar samples, meteorites, and extraterrestrial dust particles will be continued in FY 1990 to determine their chemical and physical properties and thereby derive their origin and evolutionary history. Instrument definition activities will continue to support development of new state-of-the-art instruments with emphasis on those supporting a future mission to Saturn and its moon Titan and for a Cosmic Dust Collection Facility planned as an attached payload for the Space Station. The Mars Data Analysis Program will support continued analysis of Mars data in preparation for new Mars missions, and for continued development of the Planetary Data System to archive all planetary data for enhanced accessibility for all uses. Within Advanced Programs, advanced technology development for potential future missions will also be continued.

The FY 1990 Halley's Comet Watch funding is required to support completion of the analysis and archival of data acquired by the Halley's Comet Watch program.

During FY 1990, research will be initiated to study origins of solar systems. This activity will support theoretical and experimental research by planetary scientists, astrophysicists and biologists. It will be coordinated through special workshops which will address a sequence of topical issues concerned with, and leading to, an understanding of the origins of planetary nebulae, evolution of those nebulae to planetary systems, the growth and history of planets so formed, and the paths of various elements and compounds (including biogenic compounds) throughout that evolution. The FY 1990 funding will also provide for continued operations of both the Infrared Telescope Facility and the Lunar Curatorial Facility.

EARTH SCIENCE AND APPLICATIONS PROGRAM

FY 1990 BUDGET REQUEST \$434,300,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Upper atmosphere research satellite mission.....	\$94,200,000	\$73,900,000
Ocean topography experiment.....	83,000,000	72,800,000
Scatterometer.....	10,600,000	13,800,000
Earth science payload instrument development	46,400,000	66,500,000
Mission operations and data analysis.....	17,600,000	24,800,000
Interdisciplinary research and analysis.....	2,200,000	2,300,000
Upper atmosphere research and analysis	31,100,000	38,100,000
Ocean processes research and analysis	20,800,000	24,500,000
Atmospheric dynamics/radiation research and analysis.....	32,000,000	37,400,000
Land processes research and analysis.....	19,900,000	22,500,000
Airborne science and applications	23,000,000	19,700,000

	1989 current estimate	1990 budget request
Geodynamics	32,900,000	38,000,000
Total	413,700,000	434,300,000

The goals of the Earth Science and Applications program are to improve our understanding of the processes in the atmosphere, oceans land surface and interior of the Earth and to advance our knowledge of the interactions among these environments. The program will provide space observations of parameters involved in these processes and will extend the national capabilities to predict environmental phenomena, both short and long term, and their interaction with human activities. Because many of these phenomena are global or regional, they can be most effectively (and sometimes only) observed from space. NASA's programs include scientific research efforts plus the development of new technology for global and synoptic measurements. NASA's research satellites, Shuttle/Spacelab payload program and Airborne Science and Applications program provide a unique view of the planet Earth; its physical dynamics, and radiative and chemical processes which affect habitability and the solar-terrestrial environment.

A number of significant objectives have been established for the next decade. These include advancing our understanding of the upper atmosphere through the determination of the spatial and temporal distribution of ozone and select nitrogen, hydrogen, and chlorine species in the upper atmosphere and their sources in the lower atmosphere; characterizing the current state of the terrestrial landscape, including the biosphere and the hydrosphere; optimizing the use of space-derived measurements in understanding large scale weather patterns; advancing our knowledge of severe storms and forecasting capabilities, ocean productivity, circulation, and air-sea interactions; and improving the knowledge of seasonal climate variability leading to a long-term strategy for climate observation and prediction. Studies of the cycling of key biogeochemical elements, interactions between the biosphere and the climate system, the composition and evolution of the Earth's crust and the processes that shape the Earth's crust are essential to our understanding the global environment.

Effective utilization of remote sensing requires a balanced set of activities including: analytical modeling and simulation; laboratory research of fundamental processes; development of instrumentation, flight of the instruments on the Space Shuttle, research satellites and airborne platforms; collection of *in situ* ancillary or validation data; and, scientific analysis of data. The approach is to develop a technological capability with a strong scientific base and then collect appropriate data through remote and *in situ* means, which will address specific program objectives.

The geodynamics research objectives include determination of the movements and deformation of the Earth's crust, the processes which drive tectonic plates, the rotational dynamics of the Earth and its interactions with the atmosphere and oceans, the Earth's gravity and magnetic fields, and the interior structure and compo-

sition of the Earth. These objectives require precise measurements of crustal movements and Earth orientation over an extended period with accurate knowledge of the Earth's geopotential fields and their variability.

The Upper Atmospheric Research Satellite (UARS) will place a set of instruments in Earth orbit which will make comprehensive measurements of the stratosphere, providing data about the Earth's upper atmosphere in spatial and temporal dimensions which are presently unattainable. Instrument deliveries are scheduled during FY 1989 with integration into the observatory occurring during FY 1990, consistent with the planned launch in late FY 1991.

Design and development activities are being continued in FY 1990 on the NASA Scatterometer (NSCAT), which will acquire global ocean data for operational and research use by both military and civil users. Due to cancellation of the Navy Remote Ocean Sensing System (N-ROSS) program, the Scatterometer is currently targeted for launch aboard Japan's ADESO mission in 1995. Instrument selection for ADEOS is expected during FY 1989.

Development of the Ocean Topography Experiment (TOPEX) will continue in FY 1990 toward a planned FY 1992 launch. The objective of TOPEX is to acquire precise observations of the surface topography of the ocean. These data, in conjunction with NSCAT, will enable the first determination of the wind forcing and ocean-current response of the global oceans. Spacecraft development efforts have begun at Fairchild and the Jet Propulsion Laboratory.

The Nimbus spacecraft continues to collect unique data which is being used in the study of long term trends of the Earth's atmosphere, oceans and polar ice, and provides near real time data. The Earth Radiation Budget Experiment (ERBE) was successfully launched in 1984 and continues to provide valuable data. NASA is also continuing to support the National Oceanic and Atmospheric Administration (NOAA) by managing the implementation of the polar orbiting NOAA and Geostationary Operational Environmental Satellites (GOES) series on a reimbursable basis.

The objectives of the Shuttle-Spacelab payload development program are to develop, test and evaluate Earth-viewing remote sensing instruments and systems to obtain data necessary to conduct basic research projects as well as provide correlative and developmental feasibility information for major free-flying spacecraft. Current instrument developments include the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS); Active Cavity Radar (ACR); Light Detection and Ranging (LIDAR); Shuttle Imaging Radar-C (SIR-C). Earth Observing System (EOS) advanced technology development studies continues. Proposals submitted in response to the EOS Announcement of Opportunity (AO) are presently under review. Definition instrument studies will be conducted based on the AO selection results. The EOS studies represents NASA's contribution to the U.S. Global Change Research program described in a separate document accompanying the FY 1990 budget entitled "Our Changing Planet: A U.S. Strategy for Global Change Research".

UPPER ATMOSPHERE RESEARCH SATELLITE MISSION

	1989 current estimate	1990 budget request
Spacecraft.....	\$49,300,000	\$20,000,000
Experiments.....	44,900,000	53,900,000
Total.....	94,200,000	73,900,000
STS Operations.....	(13,200,000)	34,700,000)

The Upper Atmosphere Research Satellite (UARS) program is the next step in conducting a comprehensive program of research, technology development and monitoring of the upper atmosphere aimed at improving basic scientific understanding. This mission, scheduled for an STS launch in FY 1991, is essential for understanding the key radiative, chemical and dynamical processes which couple together to control the composition and structure of the stratosphere. The UARS mission will provide the first integrated global measurements of: ozone concentration; chemical species that affect ozone; energy inputs; temperature; and winds in the stratosphere and mesosphere. These measurements will complement the measurements of ozone and of atmospheric parameters affecting ozone that were made on Nimbus and SAGE. The UARS program is a critical element in overall stratospheric research and monitoring efforts; it will provide the first full data set on stratospheric composition and dynamics which will be required when very difficult decisions must be made in the future regarding production of chlorofluorocarbons. The UARS mission will also contribute to the assessment of the impact of stratospheric changes on our climate and will provide the data needed for a full understanding of the stratosphere. These understandings are essential for subsequent design and implementation of a long-term stratospheric monitoring activity. A final selection of ten experiments has been made, including infrared and microwave limb sounders which require advances in cryogenics, solid-state devices and microwave antennas beyond earlier capabilities. The instrument design and development activities are underway. A Solar Backscatter Ultraviolet (SBUV) instrument will be modified to fly on the Shuttle during the UARS mission and to provide correlative data. In addition, development of the central ground data handling facility, which will permit near-realtime interactive utilization of data by the twenty-one design and theoretical investigator teams, is underway.

The FY 1990 funds will provide for continuation of the development activities on the ten UARS instruments including flight hardware fabrication, instrument assembly and environmental testing and instrument integration to the spacecraft. The spacecraft development and hardware fabrication activities will continue, including completion of the spacecraft mechanical test model program and the completion of spacecraft integration and test in late 1989.

The ground data handling facility will enable a higher level of interaction among experimenters and theoreticians than has existed with past programs. Implementation of this concept requires that the system be developed on a timely parallel path with the

flight hardware so that individual experiment data processing subsystems, including algorithms and the interactive data base, provide maximum interaction and effectiveness in the design and development phase of the program and are fully verified at launch time. In order to achieve this, FY 1990 funding is required to complete design and development of the ground data handling facility including hardware delivery and checkout, software preliminary and critical design reviews, science team support and science algorithm development.

OCEAN TOPOGRAPHY EXPERIMENT

Ocean topography experiment (TOPEX):

1989 current estimate.....	\$83,000,000
1990 budget request.....	72,800,000

The goal of the Ocean Topography Experiment (TOPEX) is to utilize satellite radar altimetry to measure the surface topography of the global oceans over a period of three years with sufficient accuracy and precision to significantly enhance our understanding of the oceans' general circulation and its mesoscale variability. The capability of satellite altimetry to address this goal was demonstrated in 1978 by NASA's Seasat program. Such information is needed to better understand how the atmosphere drives the circulation of the oceans, how the oceans in turn influence the atmosphere and ultimately, the role of the oceans in climate.

NASA and the French Space Agency (CNES) are collaborating on TOPEX in order to more fully exploit the scientific value of the data. In exchange for this scientific collaboration and the flight of a French altimeter and tracking system, CNES will launch TOPEX in FY 1992 on an Ariane launch vehicle. TOPEX is also being planned in concert with the World Ocean Circulation Experiment (WOCE), a major international oceanographic field program being planned under the auspices of the World Climate Research Program (WCRP). WOCE will combine satellite observations from TOPEX with traditional *in situ* observations to enable the first comprehensive determination of the three-dimensional current structure of the global oceans. When further combined with measurements from the NASA Scatterometer (NSCAT), unique measurements of the oceans' winds and the resulting response will have been obtained. During FY 1989, the joint NASA/CNES Science Team will continue to meet; the satellite contract will continue into the development phase, Critical Design Reviews (CDR's) for the satellite, sensors, and ground data system will be held, all leading to the conduct of an end-to-end system level CDR toward the end of the fiscal year.

In 1990, TOPEX will continue full-scale spacecraft system development. Final arrangements are expected to be made by CNES for the French-provided Ariane launch vehicle during FY 1989; the mission design will be refined based on input from and interaction with the Science Team; and the Science Team will confirm their post-launch research and verification plans.

SCATTEROMETER

Scatterometer:

1989 current estimate.....	\$10,600,000
1990 budget request.....	13,800,000

The Scatterometer will provide accurate, global measurements of ocean surface winds which will be useful for both oceanography and meteorology. In addition to providing wind field data, Scatterometer data will permit the first global study of the influence of winds on ocean circulation, provide data on the effects of the oceans on the atmosphere, and provide improved marine forecasting (winds and waves).

The feasibility of using the Scatterometer technique from space to accurately measure winds was demonstrated by Seasat in 1978. Definition studies conducted by NASA during FY 1983 and early FY 1984 resulted in the determination that the performance requirements, as stated jointly by the research community and the Navy, could be satisfied by utilizing system design concepts similar to those used on the Seasat Scatterometer. The major improvements include the addition of two antennas for improved wind direction determination and the addition of digital filtering to compensate for Earth rotational effects.

The Scatterometer was planned to fly on the Navy Remote Ocean Sensing System (N-ROSS) satellite in FY 1992. The N-ROSS program was cancelled in 1988 and the Scatterometer is now targeted for the Japanese ADEOS mission planned for launch in FY 1995. The current plan is to complete the Scatterometer instrument so as to preserve the ADEOS option, and then to store it until instrument selection has been completed by the Japanese, which is expected in 1989.

During FY 1989, the antenna contract will be completed and all six flight antennas will be delivered. The Traveling Wave Tube (TWT) contract is scheduled to be completed and the development of the other flight hardware items will be continued. The instrument Critical Design Review, which was delayed due to the N-ROSS cancellation, will be held and delivery of the second computer system for the ground data system will occur. Planned activities in FY 1990 include the continuation of flight hardware development leading to the beginning of flight unit integration and testing at the end of the fiscal year; the completion of software requirements definition, the initiation of detailed software design, both for the ground data and flight systems; conducting the Preliminary Design Review (PDR) for the mission operation system; and confirmation of the science team.

EARTH SCIENCE PAYLOAD INSTRUMENT DEVELOPMENT

	1989 current estimate	1990 budget request
Atmospheric payloads	\$7,100,000	\$10,100,000
Earth sensing payloads	24,800,000	32,200,000
EOS ATD	14,500,000	24,200,000
Total	46,400,000	66,500,000

The Space Transportation System offers the unique opportunity for short-duration flights of instruments. The Earth Science and Applications program has incorporated this capability into the Shuttle/Spacelab payload development activities in these important aspects: early test, checkout and design of remote sensing instruments for long duration free-flying missions; and short-term atmospheric and environmental data gathering for basic research and analysis where long-term observations are impractical. Instrument development activities support a wide range of instrumentation—from airborne to international flights of opportunity.

The objective of the Atmosphere Trace Molecules Observed by Spectroscopy (ATMOS) experiment is to make detailed measurements of gaseous constituents (e.g., hydrogen chloride, water, ammonia, methane) in the Earth's atmosphere by using the technique of infrared absorption spectroscopy. The data will help determine the compositional structure of the upper atmosphere, including the ozone layer and its spatial variability on a global scale. The instrument was launched in 1985 on Spacelab-3 and data analysis continues. It will be reflown on the Atmospheric laboratory for Applications and Science (ATLAS) series. The science results from the first flight of ATMOS were of exceptional value, and the basic capability of ATMOS to measure very low concentrations of trace species in the Earth's atmosphere was clearly demonstrated. In FY 1987, ATMOS commenced a ground observation program at Table Mountain Observatory which will continue until the instrument is readied for shipment to KSC for the ATLAS-1 mission.

The Measurement of Air Pollution from Satellites (MAPS) experiment is a gas-filter correlation radiometer designed to measure the levels of troposphere carbon monoxide and the extent of interhemispheric mass transport in the lower atmosphere. The instrument was flown successfully on two Shuttle flights, and data analysis continues. It is planned for four STS flights, one for each season of the year, to provide the first observations of the global seasonal variation of carbon monoxide in the Earth's atmosphere. Reflight of MAPS is also planned on the ATLAS series.

The Active Cavity Radiometer-1 (ACR-1) is designed to aid in the study of the Earth's climate and the physical behavior of the Sun. Reflights of ACR-1 on the ATLAS series are planned. Other experiments have also been selected for reflight, including some instruments which were flown on the Shuttle orbital flight tests, and Spacelabs-1 and -2.

The modification of a Total Ozone Mapping Spectrometer (TOMS) engineering model began in late 1988 to support flight readiness for a target launch in 1991 aboard a Soviet sun-synchronous polar orbiter. This mission will provide measurements on the horizontal distribution of the ozone shield through 1992.

Components of the Shuttle Imaging Radar-B (SIR-B) will be used in building the next generation Imaging Radar instrument, SIR-C. The SIR-C will use multi-polarized, dual frequency sensor technology. SIR-C is in the development phase; System Requirements Review, Antenna Preliminary Design Review and System Preliminary Design Review are complete. In October 1987, NASA signed a Memorandum of Understanding with the Federal Republic of West Germany agreeing to joint missions of SIR-C with an x-band imag-

ing radar to be provided by a joint German/Italian project (X-SAR). Preparations continue for commercialization of the Large Format Camera (LFC).

Advanced spectrometer technology development activities include fundamental research in remote sensing involving airborne and spaceborne imaging spectrometer instruments. The imaging spectrometer and linear array solid-state sensor research focuses on the development of such features as inherent geometric and spectral registration and programmable high spatial and spectral resolution. The critical technology development and supporting research on the Shuttle Imaging Spectrometer Experiment (SISEX) and the linear array focal plan will continue.

FY 1990 funds will be used to support the MAPS science team activities, including data reduction, refurbishment for reflight, and upgrading of the ground service equipment. The FY 1990 funding for ATMOS is required to support the ground observation program as well as continued science team activities, data processing and analysis, and limited refurbishments. FY 1990 funding is also required to continue the Active Cavity Radiometer (ACR) data processing, science team activities, and refurbishment for reflight on future Shuttle ATLAS flights, and development of a free-flyer version of ACR.

Preliminary definition of the advanced instrumentation and data facilities associated with the future Earth Observing System (EOS) will be continued in FY 1990. The EOS is intended as a payload on the Space Station's polar platform. Instrument definition and feasibility studies will be continued along with related system engineering and payload accommodation studies. A detailed review of those proposals is currently being conducted. The EOS studies represents NASA contribution to the U.S. Global Change Research program described in a separate document accompanying the FY 1990 budget entitled "Our Changing Planet: A U.S. Strategy for Global Change Research".

Development activities will continue on the international (U.S. and France) Light Detection and Ranging (LIDAR) airborne instrumentation following completion of critical design reviews in preparation for the integration, ground test and first flight in FY 1989 of this multi-phase user program. In this program, both NASA and the French are supplying science knowledge and hardware to demonstrate first-time detail measurements of the atmosphere to aid in forecasting. FY 1990 funding is required for continued development of SIR-C technology, and for advanced spectrometer activities including the development of the Shuttle Imaging Spectrometer Experiment.

Activities will continue preparing for the TOMS launch in 1991. In addition, alternate launch opportunities will be sought for applicable payloads.

MISSION OPERATIONS AND DATA ANALYSIS

	1989 current estimate	1990 budget request
Operations for the extended mission of:		
Nimbus 7	\$3,400,000	\$3,400,000
Solar mesosphere explorer (SME).....	100,000	
Correlative measurement/solar backscatter ultraviolet instrument.....	2,200,000	7,000,000
Earth radiation budget experiment extended operations.....	9,600,000	10,400,000
Shuttle imaging radar-B.....	2,300,000	4,000,000
Total	17,600,000	24,800,000

The objective of the mission operations program is to provide for the operations, data processing validation and data analysis of missions which have completed basic operations.

Launched in 1978, the Nimbus-7 spacecraft continues to provide significant quantities of both atmosphere and solid Earth global data for multi-discipline investigations and applications. These include atmospheric dynamics and chemistry resulting in global ozone measurements that are helping to understand the complicated heat exchanges of the atmosphere-ocean system, and, for the first time, global ocean data and sea ice concentration as well as properties of both polar caps. NASA supplies this unique sea ice concentration data in near real-time to the joint U.S. Navy-NOAA Ice Center. The ocean color measurements provide the only data on open ocean and coastal area chlorophyll concentration which relates to abundance of phytoplankton, the basic element of the ocean food chain. Current studies of complete ocean basins are expanding the understanding of global productivity. Nimbus-7 operations and data reduction/validation activities will continue in FY 1990 to support the strong demand for data.

The Solar Mesosphere Explorer (SME), launched in October 1981, continues to provide solar irradiance data. SME data analysis results allow us to better understand the complex chemical processes taking place in the mesosphere through scrutiny of data measurements of ozone, atomic oxygen, nitric oxide and solar irradiance. Data results indicate greater short-term variations and magnitude than was expected of many of the mesospheric properties.

The Correlative Measurements program serves to compare and/or correct data gathered by Nimbus and other NOAA meteorological satellites. Reprocessing of data from the Solar Backscatter Ultraviolet Spectrometer (SBUV) will continue in FY 1990 as a complement to ongoing Nimbus-7 operations.

The Earth Radiation Budget Experiment (ERBE) and its component Stratospheric Aerosol and Gas Experiment (SAGE) measure temporal variations in the Earth's radiation budget and ozone gases, in order to gain basic insight into the causes of climatic fluctuations.

Design and definition studies for the Japanese Earth Resources Satellite (JERS) will continue in FY 1990. Discussions with the Japanese government regarding the possibility of direct readout of

Synthetic Aperture Radar (SAR) data from this satellite at NASA's Alaska SAR Facility have been initiated.

Operation of the Nimbus satellite and processing of the collected data will be continued as will activities to provide ground truth for a NASA-developed ozone instrument to be flown on a NOAA meteorological satellite. The Nimbus satellite continues to provide extremely valuable data on ozone concentrations which will be used to estimate the occurrence of natural and man-made variations, sea surface temperatures, aerosol measurements, and ocean productivity. Correlative ground truth activities will also be continued in FY 1990; these *in situ* observations are needed to verify the quality of remote observations and improve our ability to interpret them.

In addition, FY 1990 funding is required for operating the ERBS spacecraft, data processing and analysis from the total three-instrument system, and from the SAGE-II instrument on ERBS.

INTERDISCIPLINARY RESEARCH AND ANALYSIS

Interdisciplinary research and analysis:

1989 current estimate.....	\$2,200,000
1990 budget request	2,300,000

Interdisciplinary research activities need to be conducted to quantitatively characterize the Earth's chemical, physical, and biological processes on the land, along with the interactions between the land, the oceans, and atmosphere, which are of particular importance in assessing the impact of these phenomena on global, physical, and biogeochemical processes. Such research is essential to investigating and assessing long-term physical, chemical, and biological trends and changes in the Earth's environment. Included in the program activities are joint efforts from a variety of disciplines, including atmospheric science, climatology, biological sciences, geochemistry, and oceanography.

In FY 1990, interdisciplinary studies will be continued with emphasis on integrating discipline-specific research activities of Oceanic Processes, Atmospheric Dynamics and Radiation, Upper Atmosphere/Troposphere Chemistry, and Land Processes into a unified program which will help increase our understanding of critical global processes. Emphasis will be placed on specific pilot studies such as those understanding the biogeochemical processes controlling the concentration of atmospheric methane, characterizing changes in properties of the land surface and their effect on climate, and understanding the role of the oceans in the global carbon cycle.

UPPER ATMOSPHERE RESEARCH AND ANALYSIS

	1989 current estimate	1990 budget request
Upper atmospheric research	\$18,900,000	\$23,100,000
Stratospheric process	6,400,000	7,900,000
Tropospheric chemistry	5,800,000	7,100,000
Total	31,100,000	38,100,000

The Upper Atmosphere Research program is a comprehensive research and technology effort designed to investigate and monitor the phenomena of the upper atmosphere and related phenomena in the lower atmosphere. It is aimed at improving our basic scientific understanding of the global atmosphere and the methods needed to assess its susceptibility to significant chemical and physical change. The program's three major thrusts are in the areas of upper atmospheric research, stratospheric processes research, and tropospheric chemistry research.

The goal of the upper atmosphere research program is to understand the physics, chemistry and transport processes in the stratosphere on a global scale, and to assess as accurately as possible the perturbations to the atmosphere caused by man's activities. In order to accomplish this, efforts are underway to: (1) improve upper atmosphere and global troposphere models, validate them, and assess their uncertainties; (2) measure important trace chemical constituents, temperature, and radiation fields throughout the atmosphere; (3) develop sensors capable of making chemical and physical measurements of the upper atmosphere and the global troposphere both directly and remotely from space; (4) assemble and maintain the existing long-term data base of stratospheric and tropospheric ozone measurements to aid in the detection of long-timescale natural variations and man-made ozone changes; (5) determine the effects of global tropospheric chemistry on the atmosphere; (6) conduct theoretical and field studies of tropospheric/stratospheric exchange; and (7) carry out laboratory kinetics and spectroscopy investigations to support these activities. A variety of *in situ* and remote sensing techniques are needed to meet the objectives of determining and understanding the distribution of ozone and other trace species in the atmosphere. Data sets from a limited number of satellites are now generally available to the scientific community, including a record of the global distribution of ozone extending back over a decade, and simultaneous observations of a number of trace constituents. This data is being exploited to determine if trends in the ozone amount can be detected and to understand those processes which are directly involved with these trends.

Recent developments in our understanding of the ozone layer have revealed a possible non-linear dependence of ozone depletion on the amount of fluorocarbon released to the atmosphere. These findings place increased urgency on the need to verify the completeness and accuracy of the theoretical stratospheric models. In FY 1990, tests of the models will be continued by means of field measurements, model calculations, and interpretation of satellite data. The development of more realistic two- and three-dimensional models will be continued. The global data sets from past and present satellites will be further analyzed in FY 1990 to aid in the understanding of large-scale atmospheric processes.

The comparison of balloon, aircraft, and ground-based measurements will be continued in FY 1990 to ensure the validity of the different techniques that have been developed and to observe chemical species in the stratosphere and troposphere to determine the exchange of gases between the lower and upper atmosphere. These balloon and aircraft measurement programs are the only way to measure many of the localized phenomena of the atmosphere; they

also help to validate satellite observations. Studies of potential new instruments for use on future satellites and suborbital measurement platforms will also be conducted in FY 1990 to ensure that new technologies are put to use in improving the capability and cost efficiency of tropospheric composition and upper atmosphere measurements.

The recent observations of a depletion in the amount of ozone over Antarctica in the austral spring have attracted a great deal of attention. In order to understand the chemical and dynamic processes that are causing this phenomena, a major aircraft mission was conducted in late FY 1987—early FY 1988 using the NASA ER-2 and DC-8. Analysis and interpretation of the results of this mission is a critical effort in FY 1989. An Arctic and/or return Antarctic mission is planned for FY 1989 based on the results of the 1987 campaign. Data analysis and interpretation of the results of this mission will continue into 1990.

OCEANIC PROCESSES RESEARCH AND ANALYSIS

Research and analysis:

1989 current estimate.....	\$20,800
1990 budget request.....	24,500,000

The Oceanic Processes Research and Analysis (R&A) program emphasizes the development and application of spaceborne observing techniques to advance our understanding of the fundamental behavior of the oceans, as well as to assist users with the implementation of operational systems.

The Oceanic Processes R&A program is organized into three discipline areas: (1) physical; (2) biological; and (3) polar oceanography. In physical oceanography, satellite scatterometers and altimeters are used to observe surface roughness and topography, from which surface winds and ocean current response can be estimated. In biological oceanography, color scanners are used to observe chlorophyll concentration, from which primary productivity can be estimated. In polar oceanography, microwave radiometers and synthetic aperture radars are used to estimate the characteristics of sea-ice cover and the details of its motion.

The Oceanic Process R&A program operates in concert with other federal agencies (Navy, NOAA, and National Science Foundation (NSF)) and foreign countries (Canada, European, Japan), for the World Climate Research Program (WCRP). Component WCRP efforts include the Tropical Ocean/Global Atmosphere (TOGA) and World Ocean Circulation Experiments (WOCE), a Global Ocean Flux Study (GOFS) and a Program for International Polar Oceans Research (PIPOR).

In FY 1990, the physical oceanography research activities will include continuing planning for WOCE and TOGA, as well as the development of assimilation techniques to incorporate altimeter and Scatterometer data into numerical models for use in determining the general circulation of the oceans. In biological oceanography, global ocean productivity will be assessed based on analysis of Nimbus-7 Coastal Zone Color Scanner (CZCS) data, in order to assist with the conceptual design of the Global Ocean Flux Study. In addition, implementation studies will be performed with EOSAT

for potential flight of an ocean-oriented color scanner (Sea-WIFS) aboard the Landsat-6 spacecraft. In polar oceanography, emphasis will be placed on the experimental design for the Program for International Polar Oceans Research, which is planned to involve direct reception at the Alaska Synthetic Aperture Radar (SAR) Facility in Fairbanks of SAR data from the European Space Agency's ERS-1 (Earth Resources Satellite) and from the Japanese Earth Resources Satellite (JERS)-1 spacecraft, due for launch in 1990 and 1992, respectively.

Significant work on the NASA Ocean Data System will be performed in order to optimize its use as a scientific support facility for the ocean research community. NASA's activities are being coordinated with the Office of Naval Research, NSF, and NOAA in order to assure that appropriate computing facilities, data archives, and communication networks will be available for the utilization of spaceborn observations from missions planned within the next decade.

Advanced technology development activities will also be continued on prospective future sensors for flight aboard both the Shuttle and free/flying spacecraft.

ATMOSPHERIC DYNAMICS AND RADIATION RESEARCH AND ANALYSIS

	1989 current estimate	1990 budget request
Global-scale atmospheric processes research and analysis.....	\$14,500,000	\$16,900,000
Mesoscale atmospheric processes research and analysis.....	8,500,000	9,900,000
Climate research and analysis.....	9,000,000	10,600,000
Total	32,000,000	37,400,000

The research and analysis activities within the Atmospheric Dynamics and Radiation program combine a core effort which is essential in order to use space technology to address problems in atmospheric science. The three main thrusts in the program are in the areas of global-scale processes, mesoscale processes and climate research.

The objectives of the global-scale research program are to improve our understanding of large-scale atmospheric behavior and to develop improved capabilities to observe the atmosphere from space. The program involves the development of advanced remote sensing instrumentation to observe the atmosphere, the development of advanced analysis techniques to better utilize existing meteorological satellite data, and development of advanced numerical models which use satellite observations to describe the state of the atmosphere both diagnostically and predictively. Recent accomplishments include the development and application of techniques which more fully utilize passive multispectral data (IR and microwave) from the NOAA operational satellites to provide global maps of a number of key atmospheric and surface parameters. The first year of a ten-year data set of these Earth science parameters has been completed and made available to the scientific community.

Additionally, special attention has been devoted to developing active Lidar techniques to provide detailed profiles of atmospheric wind, temperature, pressure, and moisture data from future spaceborne platforms. Simulations, of these advanced techniques indicate their increased potential in greatly improving meteorological prediction capability.

The objectives of the mesoscale processes research program are to improve our understanding of the behavior of the atmosphere on short (minutes to hours) time scales and local to regional scales (severe weather, such as tornadoes and hurricanes). Since all of the characteristics parameters of these mesoscale processes cannot be measured directly, new techniques are under study to derive the information from other observations which can be directly measured. Such an activity requires advanced data handling and analysis techniques which rely upon man-computer interactive display and manipulation. In the area of remote sensor development, initial feasibility studies to instrumentation to observe lightning from space have been completed under the guidance of a joint NASA/NOA working group. This group continues to study the practical value of lightning mapping from geostationary orbit and the possibility of incorporating experimental lightning mapping observations on a GOES spacecraft. A Memorandum of Agreement with NOAA is being prepared to fly a research version of the lightning mapper on GOES-M.

The Climate Research Program seeks to develop a space capability for global observations of climate parameters to increase our understanding of the processes that influence climate and its predictability. In accordance with the National Climate Program priority, research in solar and Earth radiation is led by NASA. Future thrusts will be aligned with programs of solar irradiance monitoring, Earth radiation budget monitoring and analysis, stratospheric aerosols on the radiation budget, and on selected process studies which relate to monitoring of climate change. Selected process studies related to monitoring climate change are also included. The first results of the data phase of the International Satellite Cloud Climatology Project (ISCCP) have been successfully archived and two field experiments of the First ISCCP Regional Experiment (FIRE) have been completed. Data from ISCCP and FIRE are being analyzed in conjunction with the Earth Radiation Budget Experiment (ERBE) data to improve our knowledge of cloud-radiation interactions which affect our climate. In addition, measurements of the solar irradiance will continue through the repaired Solar Maximum Mission (SMM) spacecraft, Nimbus 7 and reflights of the Active Cavity Radiometer flown on Spacelab-1.

A significant research effort to develop the capability for observing rainfall from space continues. Studies of instruments, sampling requirements, algorithm development, and modeling indicate the feasibility of sensing rainfall from space for climatic purposes. Under a bilateral agreement with the Science and Technology Agency of Japan, NASA is cooperating in a joint study of a special mission to measure tropical rainfall. Studies to accommodate a rainfall measurement experiment on the Space Station have been initiated and will be continued.

FY 1990 funding is required for support of the Global Backscatter experiment (GLOBE). A field campaign is scheduled for GLOBE using the NASA DC-8 during FY 1990. These airborne observations and the auxiliary observations to be made from ground-based and satellite observatories will be used to determine the seasonal and geographic variations in the backscatter of laser radiation due to atmospheric aerosols. In addition to increasing our understanding of the optical properties of the atmosphere, these data are needed in the system design of the Laser Atmospheric Wind Sounder (LAWS), a facility instrument for the future Earth Observing System (EOS).

The initiative in Radiative Gas Effects is a new focus for the Climate Research program during FY 1990. In particular, plans for the detection of greenhouse effect on climate from space observations will be pursued. The plans call for: (1) the identification of the required spaceborne measurements, process studies, and modeling improvements needed for early detection of the climatic effects of changing atmospheric composition; and, (2) the development of a NASA interdisciplinary research strategy for acquiring the technology and knowledge needed for understanding the regional and global climatic implications of projected greenhouse changes.

FY 1990 funding is required to provide instruments and support for aircraft flights to study the detail of flows around thunderstorms and weather fronts, continue development and comparison of numerical models, study atmospheric scale interactions, and develop techniques to display model outputs in four-dimensions. Continued analysis of the data collected in interagency field experiments during FY 1986 and 1987 will be performed. These data include the results of the Genesis of Atlantic Lows Experiment (GALE), the Cooperative Huntsville Meteorological Experiment (COHMEX) and the First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE). In addition, experimental, theoretical, and computational work will be done to better define the capabilities and the requirements for the remote measurement of rainfall. Other activities will involve continued retrieval and archiving of global International Satellite Cloud Climatology Project data sets, analysis of data from the Earth Radiation Budget Experiment and the Stratospheric Aerosol and Gas Experiment, and continued ground-based and rocket flight support for solar irradiance monitoring. Technology development of active temperature, pressure, and moisture sounders as well as basic Lidar technology development will also be continued in FY 1990. Preliminary planning, experiment design, and technology development will begin for the large, multi-agency STORM program to evaluate the research and operations potential of new meteorological remote sensors such as: the sounder on GOES-NEXT, NEXRAD, AWIPS-90, ASOS, SSM/I, AVHRR-3 and high-altitude active and passive sensors to estimate precipitation.

LAND PROCESSES RESEARCH AND ANALYSIS

Research and analysis:

1989 Current estimate.....	\$19,900,000
1990 budget request.....	22,500,000

Land Processes Research and Analysis concentrates on three distinct categories of land-related change processes: biogeochemical, hydrology, and geology. The broad goal of the Biogeochemical Processes program is to achieve an improved understanding of the role of terrestrial biota in processes of global significance through the use of airborne and spaceborne sensors. Specific objectives are to understand biogeochemical processes and cycles, biotic contributions to the global energy balance, and change in vegetation state and dynamics.

The goals of the Hydrology program are to use remote sensing to achieve a better understanding of the regional and global storages and fluxes of the land component of the Earth's hydrologic cycle, to investigate the role of the hydrologic cycle in regional and global biogeochemistry, and to examine the interactions between land surface processes and regional and global climate.

The goal of the Geology program element is to derive a better understanding of the Earth's geology, geologic history, and the processes that have shaped the surface of the Earth over geologic time using spaceborne sensors. Specific objectives are: to investigate the history and evolution of the continents from early formation through accretionary, depositional, tectonic, deformational, and presently active erosional processes; and, to investigate quaternary geologic history and processes in order to unravel the course of recent geomorphic, volcanic and climatic processes for a better understanding of the evolution of land surfaces and climate over the last million years. The Remote Sensing Science program is a cross cutting activity which supports the three other disciplinary program elements through theoretical modeling and field measurements of land surface properties. At this time the focus is on obtaining a firm understanding of the physical and biological factors which control the interaction of electromagnetic radiation with the Earth's surface. The aim is to develop the capability to determine surface properties with remote sensing using only a minimum reliance on empirical or statistical techniques.

In FY 1990 emphasis will be on investigations using multiple sensors operating in the visible, near-infrared, shortwave infrared, thermal infrared, and the microwave. Advanced airborne instruments which are prototypes for the future Earth Observing System (EOS) will be used in a variety of geologic, ecological and hydrological experiments. The theoretical basis for the use of combined sensors will be developed within the Remote Sensing Science program element. Current theoretical models will be used in the design of these experiments which will be designed to meet specific scientific goals in the other program elements.

As a part of NASA's program for the study of Global Change, there will be a series of multitemporal ecosystems studies using the airborne prototypes of EOS instruments. Vegetation is dynamic over a growing season, and remote sensing coverage at an instant in time only captures one stage of the annual cycle. Repetitive coverage of selected sites offers the opportunity to study dynamic properties of ecosystems. We plan to select a small number of sites to be scheduled for multiple data acquisitions spanning the growing season and to encourage several investigators to conduct investigations at any one site.

Operational satellite systems will be used in conjunction with the advanced airborne sensors. Multiyear data sets from the Landsat Multispectral Scanner, the Advanced Very High Resolution Radiometer (AVHRR) and the Scanning Multifrequency Microwave Radiometer (SMMR) will be used to study global change on the decadal scale. Global data sets will be maintained using the AVHRR and the Special Sensor Microwave Imager (SSM/I), which replaces the SMMR.

The International Satellite Land Surface Climatology Project's (ISLSCP) First ISLSCP Field Experiment (FIFE), will continue. Guest investigators will be supported to broaden the base of users of this comprehensive data set, and mechanisms will be established to make the data available to other investigators.

AIRBORNE SCIENCE AND APPLICATIONS

Airborne science and applications:

1989 current estimate.....	\$23,000,000
1990 budget request.....	19,700,000

This effort covers operation of two ER-2's, a C-130, and DC-8 aircraft in order to support Earth-sensing and atmospheric research. The DC-8 was acquired to replace the CV-990 research facility, "Galileo II", which was destroyed by fire in 1985. The replacement DC-8 has undergone required upgrades and modifications and carried out initial operations in Antarctica in 1987 as part of the Ozone Hole campaign. Acquisition of a second ER-2, to replace the aging U-2C's, will be completed in FY 1989. These aircraft support other major segments of the Space Science and Applications program dealing with the Earth, the oceans, and the atmosphere. They may serve as test beds for newly developed instrumentation and allow demonstration of new sensor techniques before their flight on satellites or on Shuttle/Spacelab missions. Data obtained from these aircraft are used to refine analytical algorithms, and to develop ground data handling techniques. For example, the ER-2's acquire stratospheric air samples and conduct *in-situ* measurements at altitude ranges above the capability of more conventional aircraft and below those of orbiting satellites. This capability is important in gaining an understanding of stratospheric transport mechanisms.

Requested FY 1990 funding will allow operation and required maintenance of all aircraft. Operations will allow continuation of such projects as the collection and analysis of stratospheric air samples, testing of newly developed instrumentation, the demonstration of new sensor concepts, the investigation of the Ozone Hole phenomena, and participation in numerous other field experiments such as First International Satellite Cloud Climatology Project (ISCCP) Regional Experiment (FIRE).

GEODYNAMICS

	1989 current estimate	1990 budget request
Crustal dynamics project	\$18,200,000	\$21,200,000
Laser network operations	8,800,000	9,600,000

GEODYNAMICS—CONTINUED

	1989 current estimate	1990 budget request
Research and technique development	5,900,000	7,200,000
Total	32,900,000	38,000,000

The objective of the Geodynamics program is to understand the origin, evolution, and current state of the solid Earth by measuring the movement and deformation of the tectonic plates and by measuring its rotational dynamics and potential fields. Laser ranging to satellites and the moon, microwave interferometry using astronomical radio sources and transmissions from the Global Positioning Satellite System (GPS) are used to determine precise position locations. The global gravity and magnetic fields are determined from satellite observations.

Measurements over the past years have provided experimental determination of the velocities of several of the major tectonic plates. Measurements of regional deformation across the San Andreas Fault continue to indicate a relative movement of the Pacific and North American Plate of about 6 cm per year. In addition, measurements indicate that about 4 cm of this movement is occurring in Southern California. Measurements of polar motion and changes in the length of a day have been correlated, to a high degree, with variations in the angular momentum and the inertial balance of the Earth's atmosphere due to high altitude winds. The Earth's rotation was found to have slowed by five milliseconds due to the El Nino effect. The Earth's rotational dynamics are also influenced by motions of the Earth's core and the oceans. Models of the Earth's gravity field, derived from Laser Geodynamics Satellite (LAGEOS-1) data have provided the first evidence of gravity field variations. These variations are believed to be caused by continued relaxation of the crust following the last ice age and have confirmed estimates of the viscosity of the Earth's mantle layer. Analysis of the magnetic field, using data from Magsat, has confirmed the diameter of the Earth's outer core and has provided new data on secular variations of the magnetic field.

The United States and a consortium of eight European and middle East countries continue measurements of crustal deformation in Greece, Turkey, and Italy. In 1988, a mobile Laser Ranging Station operated by the Federal Republic of Germany will join similar U.S. stations in deformation studies in the U.S.

Development of instrumentation and techniques for use of the DOD Global Positioning System (GPS) for rapid crustal motion measurements has continued. The geodetic techniques developed by NASA for measurement of polar motion and Earth rotation have been adopted by the International Union of Geodesy and Geophysics (IUGG) as the basis of the new International Earth Rotation Service. Within the U.S., NOAA and the U.S. Naval Observatory (USNO) have adopted Very Long Baseline Interferometry as the basis for the National Earth Orientation Service.

Studies continued to confirm the need for improved gravity and magnetic field measurements. While considerable advances have been made in modeling the gravity field, new data are needed to achieve the resolution and accuracies required for solid Earth research. Laboratory development of a supercooled gravity gradiometer are continued, and plans are being made for a Shuttle test of this technology. Joint studies are underway with the French on a cooperative Magnolia/Magnetic Field Satellite for extensive, long-duration studies of secular and temporal changes of the main magnetic field.

In FY 1990, measurements of plate motion between North America and Europe will be continued in cooperation with countries in Europe, the Middle East, Far East, South and Central America. Measurements of the motions of the Pacific Plate will be continued in cooperation with Japan and China. Regional crustal deformation measurements in western North America will continue in cooperation with NOAA, Canada and Mexico. The Caribbean studies will be continued and include more sites along the plate boundary and on the plate itself.

LAGEOS-1 and other satellites will continue to be used for studies of plate motion. NASA systems in the U.S., Pacific, South America, and Australia will be operated in cooperation with laser systems in 12 other countries. The LAGEOS-2, a joint mission with Italy, is presently under development by Italy and will be launched by the U.S. Theoretical studies of crustal motion, internal Earth structure and composition, and the modeling and interpretation of geopotential fields will be continued in FY 1990. In addition, system studies of a second magnetic field satellite for long-term measurements of the Earth's field (Magnolia/MFE), studies of geopotential research, and laboratory development of room-temperature and cryogenic gravity gradiometer instrumentation will continue.

MATERIALS PROCESSING IN SPACE PROGRAM

FY 1990 BUDGET REQUEST \$92,700,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Research and analysis	\$13,600,000	\$13,000,000
Microgravity shuttle/space station payloads	56,400,000	74,600,000
Commercial microgravity R&D enhancements	5,600,000	5,100,000
Total	75,600,000	92,700,000

The mission of the Microgravity Science and Applications program is to foster the development of near-Earth space as a natural resource by exploiting microgravity and other unique attributes that may be attained in an orbiting spacecraft. In this environment, we can advance knowledge about the fundamental nature of matter, increase understanding of the role of gravity in various industrial processes, and produce limited quantities of certain exotic high-value materials for specialized applications. In FY 1990,

ground-based research and payload development will be concentrated in six major areas: metals and alloys, electronic materials, glasses and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena.

During FY 1990, ground-based research will support definition studies for Shuttle and Space Station experiment candidates in areas such as containerless experiments, solidification and crystal growth, and processing of biological materials. Researchers will conduct experiments in drop tubes, towers and aircraft.

The Microgravity Shuttle/Spacelab Payloads program provides a range of experimental capabilities for all participants in the Materials Processing in Space program. The payloads program currently supports a wide variety of hardware development, from unique flight experiments necessary to conduct basic research into the fundamental nature of matter to the modular, multi-user research facilities that will be the cornerstone of microgravity science and applications research on the Space Station. Experiments will be flown on Shuttle and Spacelab, as well as any appropriate commercial space facility.

RESEARCH AND ANALYSIS

Ground-based investigations, analysis and studies:

1989 current estimate.....	\$13,600,000
1990 budget request	13,000,000

The research and analysis activity provides the scientific foundation for all current and future projects in the Microgravity Science and Applications program. Emphasis is placed on ground-based research which is expected to evolve into space investigations with potential for future applications. This activity also supports technology development for future ground and space capabilities, and applications activities leading toward privately-funded space enterprises. Most research projects are initiated as a result of proposals from the scientific community which are extensively reviewed by peer groups prior to selection.

Ground-based research and analysis will be continued in FY 1990 in the areas of metals and alloys, electronic materials, glass and ceramics, biotechnology, combustion, and fluid dynamics and transport phenomena. Research will be conducted to define the role of gravity-driven influences in generic processing methods. Effort will continue at the Centers for Excellence located at the Massachusetts Institute of Technology, the University of Colorado, and the University of Arizona, as well as the Microgravity Materials Science Lab at the Lewis Research Center.

MICROGRAVITY SHUTTLE/SPACE STATION PAYLOADS

Materials experiment operations:

1989 current estimate.....	\$56,400,000
1990 budget request	74,600,000

The Microgravity Shuttle/Space Station payloads program provides a wide range of opportunities for experiments in microgravity science and applications. NASA currently supports the development of STS middeck, Spacelab and cargo-bay experiments. This policy maximizes the effective use of the STS by matching an ex-

periment with the hardware location best suited to meet its scientific and technical requirements. In some cases, the payload program supports an evolutionary program of testing flight experiment concepts in the mid-deck before committing to more complex and ambitious Spacelab or cargo-bay mounted hardware.

The Materials Processing in Space program is preparing to use Space Station as a major platform for conducting microgravity research. During FY 1989, NASA received funds from Congress to begin technical definition of six major multi-user research facilities designed to take advantage of Space Station's unique capabilities. NASA's Microgravity Science and Applications Division (MSAD) has developed a strategy for orderly evolution of microgravity experiments from ground-based research to the Shuttle, and finally to Space Station. During FY 1989 and FY 1990, MSAD will continue Space Station hardware definition, as well as equipment development for both the first United States Microgravity Laboratory Spacelab mission, and any appropriate commercial space facility. In addition to the Space Station Initiative, the Materials Processing in Space program is placing increased emphasis on NASA's Physics and Chemistry Experiments (PACE) program, which uses microgravity research to challenge and improve existing scientific theory about the fundamental nature of matter. As other nations increase their ability to exploit the characteristics of near-Earth space, the "cutting edge" experiments generated by the PACE program will play an increasingly important role in assuring continued U.S. leadership in microgravity research.

FY 1990 funding is required to continue basic and applied research activities using STS middeck, Spacelab and cargo-bay experiments leading to several flights over the next few years. Investigations are planned in fluid dynamics, glasses, electronic materials, biotechnology, metals and alloys, and combustion. Development will continue on a number of Physics and Chemistry Experiments (PACE) as well as several pieces of advanced equipment in the areas of electronic crystal growth, biotechnology, metals and alloys, and containerless processing.

COMMERCIAL MICROGRAVITY R&D ENHANCEMENTS

Commercial microgravity E&D enhancements:

1989 current estimate.....	\$5,600,000
1990 budget request.....	5,100,000

The Commercial Microgravity R&D Enhancements budget supports several projects formerly managed by NASA's Office of Commercial Programs (OCP). It consolidates funding for two joint Office of Space Science and Applications and Office of Commercial Programs multi-user research facilities—the Metals and Alloys Solidification Apparatus and Crystal Growth Furnace. The program also covers the cost of modifying existing microgravity research hardware to accommodate the commercial user community.

The FY 1990 Commercial Microgravity R&D Enhancements budget supports continued development of the Metals and Alloys Solidification Apparatus and the Crystal Growth Furnace for flight on the United States Microgravity Laboratory series, and will pro-

vide funding needed to accommodate commercial users on existing flight hardware and ground-based microgravity research facilities.

COMMUNICATIONS PROGRAM

FY 1990 BUDGET REQUEST \$18,600,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Advanced communications technology satellite (ACTS).....	\$74,600,000	
Advanced communications research.....	11,886,000	\$12,700,000
Search and rescue	1,350,000	1,300,000
Radio science and support studies	2,900,000	3,100,000
Communications data analysis	1,464,000	1,500,000
Total	92,200,000	18,600,000

Advanced communications research continues to provide the development of subsystem component technology required by NASA, other government agencies, and U.S. industry for advanced communications satellite systems. Special emphasis is being given to technologies with high potential for improving spectrum utilization, satellite switching, and intersatellite link technologies, since these technologies are the key to future growth of the communication satellite and terminal markets. The mobile communications technology program will complete development of critical enabling technologies needed to insure growth of a commercial mobile satellite service in the U.S.

The Search and Rescue program is an international cooperative program that demonstrates the use of satellite technology to detect and locate aircraft or vessels in distress. The United States, Canada, France, and the Soviet Union developed the system, in which Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India also participate.

Radio science and support studies provides the technical basis to support U.S. and NASA interests in international and domestic communications regulatory forums. Propagation studies and measurements are performed in order to understand and account for the effects of propagation in the design and specification of space communications systems. Studies to enable new satellite applications are conducted.

Communications data analysis assists other federal agencies and public sector organizations in the development of experimental satellite communications for emergency, disaster and public service applications. The main areas of work will be preparation for future optical communications experiments and operation of the Applications Technology Satellite (ATS-3), launched in 1967.

Funding has not been included for continued development of the Advanced Communications Technology Satellite (ACTS) in FY 1990. It continues to be the Administration's policy that this flight demonstration project is more appropriately and effectively under-

taken by the private sector, without subsidy or possible competition by the government.

ADVANCED COMMUNICATIONS RESEARCH

Advanced communications research.

1989 current estimate.....	\$11,886,000
1990 budget request	12,700,000

The advanced communications research program emphasizes the development of high-risk technology required to maintain U.S. pre-eminence in the international satellite communications market, to enable new and innovative public services, and to meet the communications needs of NASA and of other government agencies. This program focuses on the "interconnectivity technologies" of on-board switching, intersatellite links, and antennas, as well as advanced optical and radio frequency technologies. Advanced studies are performed to determine the future satellite communications needs of the country and to define the technology required to meet those needs. The technology is developed and tested through an advanced proof-of-concept (POC) program. The POC devices and components are then integrated into a multiple terminal, satellite communications network in a laboratory where they undergo comprehensive evaluation.

The mobile satellite communications effort, in cooperation with U.S. industry, Canada, and other government agencies, will help implement a first generation commercial system. In FY 1988, a consortium of commercial firms was formed to introduce mobile satellite communications in the U.S. The mobile satellite communications work is consistent with the objective of the communications program to develop high-risk technology, thereby insuring the progress of a U.S. mobile satellite communications industry as a commercial application of space technology. The NASA role in future mobile communications technologies research will be aimed at testing power, bandwidth and orbital-slot efficient ground segment technology, and networking techniques.

In FY 1989, work is continuing on advanced communications technologies. The optical space communications work, employing very low power lasers, will permit communications between satellites and ground terminals, satellites and low Earth-orbiting spacecraft, such as the Space Shuttle or Space Station, and between satellites and other geosynchronous orbiting satellites, such as the Tracking and Data Relay Satellite (TDRS). Technology development is also underway in the area of monolithic microwave integrated circuits (MICC), which have significant potential for applications in multi-port spacecraft matrix switches, low noise receivers, and multibeam antenna arrays and beam-forming networks. A number of industry studies are being sponsored to assess new areas of communications technologies required for the 1990's.

The Research and Analysis program will continue to support development of the technologies necessary for future space communications satellite systems, encompassing both optical and radio communications technologies.

SEARCH AND RESCUE

Search and rescue:

1989 current estimate.....	\$1,350,000
1990 budget.....	1,300,000

The NASA role and budget for Search and Rescue are limited to research and development that apply NASA technologies to Search and Rescue, specifically the next generation satellite-borne Search and Rescue equipment and advanced techniques that will make possible precise and timely location of downed aircraft and ships in distress. Other U.S. and international Search and Rescue partners are NOAA, Coast Guard, Air Force, Canada, France, the Soviet Union, Norway, the United Kingdom, Bulgaria, Sweden, Denmark, Switzerland, Brazil and India. The Search and Rescue satellite system was declared operational in July 1985. For the U.S., NOAA has responsibility for all aspects of operational Search and Rescue, while the Coast Guard and the Air Force perform the rescues. The NASA budget contains no funding for Search and Rescue operations in FY 1990.

The Search and Rescue program, developed by NASA and international partners, has demonstrated the feasibility of using satellites to improve detection and location of general aviation aircraft and marine vessels during emergencies. The system has received worldwide acclaim and has been credited with saving more than 1,100 lives to date.

In FY 1989, NASA research is being applied to the improvement of computer programs that analyze distress signals in order to locate them more precisely. Planning and development for the Search and Rescue system to be used after the last of the current NOAA satellite series will continue.

Funding in FY 1990 will continue the NASA-unique research and development role in the areas of Search and Rescue, including the next generation satellite-borne Search and Rescue equipment, future system planning, and advanced techniques. Consistent with interagency plans and commitments, the NASA budget contains no funding for Search and Rescue operations in FY 1990.

RADIO SCIENCE AND SUPPORT STUDIES

Radio science and support studies:

1989 current estimate.....	\$2,900,000
1990 budget.....	3,100,000

Radio science and support studies provide the technical basis for regulatory and policy development to assure the orderly growth of existing and new satellite services. Unique analytical tools are developed and used to solve problems of inter- and intrasatellite/terrestrial system interference. Emphasis is placed on orbit and spectrum utilization studies, which include the development of frequency and orbit sharing techniques and strategies, design standards, and the determination of the effect of propagation phenomena and man-made noise on performance, design, and efficient use of the geostationary satellite orbit and the radio spectrum.

During FY 1989, the radio science and support studies program will conduct propagation studies to help minimize radio signal atmospheric interference problems in space communications as well

as other advanced studies to enhance U.S. utilization of space for communications satellites.

During FY 1990, studies will continue to identify systems and technologies which make efficient use of the radio frequency spectrum and geostationary-satellite orbit. These studies will provide the technical basis to support standards development and regulatory decisions for space communications at the national and international levels. Propagation studies and measurements will also be carried out to fill the voids in data needed for design of new satellite applications for fixed communications, mobile communications, sound broadcasting, and high definition television broadcasting.

COMMUNICATIONS DATA ANALYSIS

Communications data analysis:

1989 current estimate.....	\$1,464,000
1990 budget.....	1,500,000

The objectives of communications data analysis are to support and to document a wide range of user experiments and demonstrations of the application of satellite communications. Past experiments on experimental satellites, such as the Applications Technology Satellite (ATS) series and the Communications Technology Satellite (CTS), have successfully provided users with the experience necessary to make informed decisions regarding the satellite communications functions. NASA's role to stimulate use of unique space facilities has led to wider application of commercial satellites that better meet the needs of potential users.

The main emphasis of communications data analysis in FY 1989 will be experiment definition for the optical communications program. Optical communications in space will employ very low power lasers to transmit information, much like current terrestrial fiber optics techniques. The advantages of optical space communications will be high data rates that will be needed for future Earth orbital satellite links, deep space to Earth orbital links, and Earth orbital to ground links.

Communications data analysis will continue to support Applications Technology Satellite (ATS) satellite, ATS-3, used by several government agencies and universities.

Experimental definition and data analysis for optical communications analysis will continue in FY 1990, as will communications data analysis support of ATS-3.

INFORMATION SYSTEMS PROGRAM

FY 1990 BUDGET REQUEST \$34,100,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget
Data systems	\$9,600,000	\$18,400,000
Information systems	10,300,000	15,700,000
Total.....	19,900,000	34,100,000

The information system program applies advanced computer and information systems technology to support the OSSA science program. This includes data management, scientific computing, networking, and other science information needs. The program provides on-going support to the OSSA research community through the NASA Space and Earth Sciences Computing Center (NSESOC) for super-computing resources in support of modeling and simulation efforts, and the National Space Data Center (NSSDC) for archival and distribution of data acquired from spaceflight experiments and observations.

The data systems element develops and applies advanced capabilities for managing, distributing, and analyzing data and information. This includes development of generic tools and capabilities to enhance the science productivity derived from data acquired from space flight observations and experiments.

The data systems element also incorporates the OSSA computer communications for science network activity. The computer communications for science network will extend scientists' access to space data and computational resources and simplify communications and collaboration among NASA's space science and applications communities. Through FY 1988, the NASA science networks were funded as part of the program support communications network. In FY 1989, the network is funded by OSSA science missions and disciplines. Beginning in FY 1990, computer communications for science network is an element of the data systems budget.

Included in information systems is a new emphasis on science data management and archival to provide the OSSA research community with a faster, more reliable system to assimilate, archive, and distribute data. With the return of the Shuttle to operational status, a six-fold increase in data holdings is expected, resulting from missions like Cosmic Background Explorer, Roentgen Satellite, Gamma Ray Observatory, International Solar Terrestrial Program, and Upper Atmospheric Research Satellite, and Spacelab missions. OSSA researchers will benefit from automated retrieval of off-line data from large archives, implementation of a master directory for location of distributed data sets by researchers, catalog inter-operability of common searches across distributed databases, delivery of data on advanced media as requested by users, and utilization of data exchange standards to facilitate automated assimilation of data by user applications. The augmentation will build on the information systems program to emphasize standards, to evolve a unified but distributed system for managing data and information, and to evaluate changing technology options in a system framework.

During FY 1989, the information systems program will emphasize planning and preparation for the return to flight status of the OSSA program and the unprecedented volume of new data expected. Implementation of data catalogs and data networks are part of an effort to maintain the efficiency of the OSSA research community. In addition, existing data archives and computing facilities will be maintained.

The FY 1990 information systems program will continue emphasis on the application of computer science technologies to support the work of the NASA science disciplines. Funding is included for

continued operation of the NSESCC and NSSDC. The information systems program will continue to develop common software to support ongoing research in the space and Earth sciences. An invigorated data management and data archival program will begin to support flight projects and science research disciplines. In FY 1990 the funds required for science network communications are consolidated in the data systems program. These requirements were previously funded in the individual space science and applications missions and disciplines, and account for an increase of \$7.5 million to the Information Systems budget.

COMMERCIAL PROGRAMS

FY 1990 BUDGET REQUEST \$61,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

Commercial programs	1989 current estimate	1990 budget request
Technology utilization	\$16,500,000	\$22,700,000
Commercial use of space	28,200,000	38,300,000
Total	44,700,000	61,000,000

TECHNOLOGY UTILIZATION PROGRAM

FY 1990 BUDGET REQUEST \$22,700,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Civil systems.....	\$2,300,000	\$3,000,000
Product development.....	1,800,000	2,400,000
Acquisition, dissemination and network operations.....	4,800,000	5,800,000
Program development, evaluation and coordination.....	1,500,000	1,700,000
Technology applications.....	3,800,000	6,800,000
Industrial outreach	2,300,000	3,000,000
Total	16,500,000	22,700,000

The NASA Technology Utilization program is designed to strengthen the national economy and industrial productivity through the transfer and application of aerospace technology resulting from NASA's R&D programs. To accomplish this objective, NASA has established and operates a number of technology transfer mechanisms to provide timely access of useful technologies to the private and public sectors of the economy. Almost every part of U.S. industry is affected by the technology transfer process, especially in such areas as automation, electronics, materials, and productivity. In the public sector, medicine, rehabilitation, transportation and safety are areas in which aerospace technologies have been especially beneficial. The specific objectives of the program are:

To accelerate and facilitate the application of new technology into the commercial sector, thus shortening the time between the generation of advanced aeronautics and space technologies and their effective use in the economy;

To encourage multiple secondary uses of NASA technology in industry, education, and government, where a wide spectrum of technological problems and needs exist;

To develop applications of NASA's aerospace technology, including its unique facilities, to priority nonaerospace needs of the Nation.

In FY 1990 Civil Systems will fund AdaNET as a program to transfer existing and emerging Ada software and other software engineering technology from the federal government to the private sector through mechanisms such as information sharing and repository services and networks. NASA, the Department of Defense, and the Department of Commerce, are participating in this program.

Based on the increasing response to Tech Briefs and expanding Industrial Applications Centers network, increases in new technology identification and reporting are anticipated in FY 1990. These resources will provide for evaluation and packaging of these technologies for publication thereby stimulating industrial interest and participation in NASA's Technology Utilization and Commercial Use of Space programs.

In FY 1990, NASA plans continued strengthening of the Technology Counselor network at its field installations to provide for expanded identification of NASA technical capabilities and expertise. This capability and expertise is necessary for matching and cross-correlating NASA technology with industry needs specified by NASA Industrial Applications Centers. To facilitate timely and efficient interaction between Technology Counselors, Industrial Applications Centers and other organizations in NASA a Technology Utilization Network System communications system is planned for functional utilization in FY 1990. Expansion of this capability, increased effective communication, and data storage and retrieval systems will greatly enhance the overall capability of the network to coordinate technology transfer activities, and respond to user efficiently with minimum overlap and duplication of effort. Moreover, the system will enable technology transfer managers to maintain appropriate controls over the process to insure overall program effectiveness and management accountability.

With an expanded role in industrial outreach, additional emphasis will be required in the development of program goals and objectives in terms of long range plans for NASA Technology Utilization (TU). Focused efforts on assessing participants in U.S. industry, preparing information guidelines to support cooperative relationships throughout the NASA technology transfer network, as well as satisfying anticipated increased demand for TU publications and responses to increased number of program inquiries are among the many management planning and support requirements. Specific actions are also planned for FY 1990 to strengthen program development, evaluation and coordination on an internal as well as external basis to support the national technology transfer network and emerging commercial use of space outreach efforts.

In FY 1990, a broadening of application team responsibilities is anticipated to assist NASA Industrial Applications Centers in bringing together industrial client problems with existing aerospace technologies leading to project definition and industry-driven cooperative projects. This effort will result in increased tangible and meaningful applications of aerospace technology in the private sector, thus enhancing the productivity and competitive posture of U.S. industry.

In FY 1990, NASA will utilize its existing dissemination center network to contact and acquaint U.S. industrial firms with opportunities to actively interact and participate with NASA in technology transfer and space commercialization. Such contacts are envisioned on a face-to-face basis, with appropriate follow-up including seminars, and conferences and workshops to explore more detailed characteristics of the "opportunities" for interaction. The NASA Industrial Applications Centers are in a unique position to serve as NASA's surrogate in aligning U.S. industrial interests in space commercialization as well as opportunities for terrestrial commercialization of advanced technologies derived from NASA's R&D programs. The technological needs of industry, would benefit from this synergistic approach designed to bring engineering resources of both in closer proximity. Successful technology transfer occurs most frequently in an environment where knowledge is shared easily and advantages through cooperative endeavors are explained and understood. It is this role that the NASA dissemination center network can readily fulfill.

COMMERCIAL USE OF SPACE

FY 1990 BUDGET REQUEST \$38,300,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Commercial applications and enhancements.....	\$25,100,000	\$34,400,000
Commercial development support.....	3,100,000	3,900,000
Total	28,200,000	38,300,000

The goal of the Commercial Use of Space program is to establish a national focus in support of opportunities for the expansion of U.S. private sector investment and involvement in civil space activities. The specific objectives of the program are to:

Establish close working relations with the private sector and academia to encourage investment in space technology and the use of the *in situ* attributes of space—vacuum, microgravity, temperature and radiation for commercial purposes.

Facilitate private sector space activities through improved access to available NASA capabilities and the development of new high technology space ventures and markets.

Encourage an increase in private sector investment in the commercial use of space independent of NASA funding.

Develop and implement commercial space policy NASA-wide.

NASA's goal of expanding opportunities for U.S. private sector investment and involvement in civil space and space-related activities is pursued through a variety of interrelated programs. Through cooperative agreements such as Joint Endeavor Agreements (JEA's) and through our support to the Centers for the Commercial Development of Space (CCDS) we will increase the amount of space-related research conducted by the private sector, the number and type of NASA and private sector facilities available for space use, and the private sector awareness of the opportunity to use NASA's terrestrial and space-based facilities for commercial research.

Resources will be made available to obtain flight support experimentation hardware required by industrial researchers. This may include across-the-bay carriers, such as Materials Science Laboratories, as well as middeck augmentation racks or derivatives thereof, and the possible leasing of private sector hardware developed to exploit commercial research and development in space. The use of ground-based research facilities, aircraft and sounding rockets for commercial experimentation will be given emphasis in order to provide limited access to the microgravity environment for appropriate commercial experiments.

In order to maintain momentum in commercial use of space activities and to encourage an increase in private sector investment in space, NASA will continue to develop methods to facilitate private sector agreements and commitments to develop commercial opportunities in space. The development of agreements for the use of the Shuttle external tanks and private sector use of U.S. launch facilities reflect this effort. The use of Space System Development Agreements (SSDA's) will continue.

Commercial applications and enhancements

In FY 1990, NASA will continue the Centers for the Commercial Development of Space (CCDS). Sixteen CCDS's have already been established in such diverse areas as space propulsion, biotechnology, materials processing, and space remote sensing. The CCDS's through space-related research conducted by the private sector and NASA, and the enhancement of private sector awareness of the availability of NASA's terrestrial and space-based facilities for potential commercial research and exploration, are a focus for the commercialization of space. Funding will be provided to increase flight readiness through projects focused to respond to industry identified requirements for hardware and flight opportunities. Continued development of space-oriented, ground-based facilities and equipment will expand the technical research data base which enables the private sector to make economic decisions to commit to space research and production. Through coordination with the private sector and the Office of Space Science and Applications, guidance will be developed and provided for the commercial microgravity research and development enhancements program.

Funding is provided for the analytical and physical integration required for Space Shuttle payloads flown under Joint Endeavor Agreements (JEA's). Direct funding is provided for reimbursable optional services which are deferred under some Space System Development Agreements (SSDA's). NASA's current SSDA's are with

Spacehab, Geostar and Space Industries Partnership. In addition, alternate launch opportunities will be sought for applicable payloads.

Commercial development support

Rapidly changing economic, commercial and technical circumstances continue to require *ad hoc* and ongoing studies by experts to provide the direction and feedback needed by the program. In FY 1990 additional emphasis will be placed on our strategic planning capability to allow us to formalize analyses and methods for implementation of an effective Commercial Space Development program and to assist in the development of agency commercial space policy. A financial analysis capability will be developed to support the analysis of potential opportunities for commercial development.

AERONAUTICS AND SPACE TECHNOLOGY

FY 1990 BUDGET REQUEST \$927,900,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Aeronautical research and technology.....	\$404,200,000	\$462,800,000
Transatmospheric research and technology.....	69,400,000	127,000,000
Space research and technology.....	295,900,000	338,100,000
Total	769,500,000	927,900,000

AERONAUTICAL RESEARCH AND TECHNOLOGY

FY 1990 BUDGET REQUEST \$462,800,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Research and technology base	\$315,563,000	\$335,700,000
Systems technology programs.....	88,637,000	127,100,000
Total	404,200,000	462,800,000

The goal of the NASA aeronautics program is to conduct research and develop technology to strengthen U.S. leadership in civil and military aviation. This goal is supported by five comprehensive program objectives: (1) emphasize emerging technologies with potential for major advances in capacity and performance; (2) maintain NASA's laboratory strength by repairing and modernizing critical aging national facilities, providing advanced scientific computational capabilities and enhancing staff technical excellence; (3) ensure timely transfer of research results to the U.S. aeronautics community through reports, conferences, workshops and cooperative research programs with industry; (4) ensure strong university involvement to broaden the nation's base of technical ex-

expertise and innovation; and (5) provide technical expertise and facility support to the Department of Defense (DoD), other government agencies, and U.S. industry for major aeronautical programs. The program is based on a strong commitment to revitalize American competitiveness in the world aviation marketplace, enhance the safety and capacity of the national airspace system, and assure U.S. superiority for national security.

In order to continue to meet the international challenge in aeronautics, the FY 1990 estimate reflects the need to address critical barriers and strengthen generic technology development in selected high payoff areas that are vital to our long-term leadership in aviation. NASA's FY 1990 aeronautics program is focused on achieving the objectives established in the report, "National Aeronautical R&D Goals: Technology for America's Future," by the Office of Science and Technology Policy (OSTP), and by its sequel report, "Agenda for Achievement."

The FY 1990 research and technology program is committed to addressing the critical issues associated with the U.S. air transportation system, to enhancing American competitiveness in the international marketplace, and preserving the country's preeminence in aviation for national security. Technologies are being pursued which, when fully implemented, could offer major advances in vehicle performance and capabilities and which could provide substantial positive impact on U.S. competitiveness. Research efforts have been expanded in high payoff areas associated with a broad range of future vehicle applications including high-performance aircraft, and high-speed transport aircraft. The demands for NASA's unique wind tunnels are continuing to increase with the emergence of new civil and military aircraft programs. In order to ensure wind tunnel availability to meet these demands, a major five-year revitalization program was initiated to modernize NASA's major wind tunnels for productive use well into the next century. This revitalization program is entering its second year in FY 1990.

A brief summary of the key elements of the research and technology base and systems technology programs follows:

Fluid and thermal physics research will continue to focus on developing faster and more efficient algorithms for numerical simulation of aerothermodynamic phenomena. In *applied aerodynamics*, the augmented research program in FY 1990 will emphasize induced drag reduction and turbulent drag reduction. *Propulsion and power* research will continue to emphasize improved fundamental understanding of stationary and rotating turbomachinery flowfields through development of advanced computational analysis methods and their applications at the component and subsystem level. *Materials and structures* research will continue to develop advanced materials and innovative structural concepts aimed at reducing aircraft weight and cost. Research in *information sciences* will continue to investigate concurrent processing architectures and algorithms for application to increasingly complex aerospace computational problems and will emphasize advanced software engineering for complex, highly reliable applications. *Controls and guidance* research will continue to provide a technology foundation in advanced systems for application to future aerospace vehicles, with emphasis on guidance and control for highly agile aircraft.

Human factors research will continue development of methodologies required for safe and effective crew/cockpit interfaces with particular emphasis on highly automated aircraft operating in the future national airspace system. *Flight systems* research will be augmented to increase emphasis on high angle-of-attack technologies through simulation, wind tunnel tests, and flight evaluation. *System analysis* studies will continue to focus on rotorcraft, and supersonic short takeoff and vertical landing fighter aircraft. In *materials and structures* systems technology, advanced composite materials research will continue in high-temperature materials while expanding its focus on application of composites to primary aircraft structures. *Rotorcraft* systems technology research will continue the FY 1989 effort in noise prediction, code validation, and envelope expansion of the XV-15 tiltrotor with advanced technology blades. In *high-performance aircraft* systems technology, flight system research will start a new focus on high-speed flight, addressing environmental issues such as ozone depletion, airport noise, and sonic boom. *Advanced propulsion* systems technology will focus primarily on high-speed turboprops with specific emphasis on improved understanding, modeling, and code validation of flowfields, structural response, noise characteristics, and installations effects. The *numerical aerodynamic simulation* capability will be enhanced with the acquisition of the third high-speed processor.

RESEARCH AND TECHNOLOGY BASE

FY 1990 BUDGET REQUEST \$335,700,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Fluid and thermal physics research and technology	32,800,000	\$33,500,000
Applied aerodynamics research and technology	68,463,000	73,800,000
Propulsion and power research and technology	70,100,000	71,500,000
Materials and structures research and technology	40,100,000	40,500,000
Information sciences research and technology	9,600,000	11,700,000
Controls and guidance research and technology	36,400,000	37,000,000
Human factors research and technology	17,700,000	17,800,000
Flight systems research and technology	30,800,000	39,800,000
Systems analysis	9,600,000	10,100,000
Total	315,563,000	335,700,000

Fluid and thermal physics research and technology

Fluid and thermal physics research is performed to advance the understanding of fundamental fluid mechanics phenomena and to derive efficient aerodynamic prediction tools. The research includes efforts in fluid physics, computational fluid dynamics (CFD), code validation, and viscous flow studies. The latter area includes laminar stability analysis, boundary layer transition, and analytical turbulence. CFD research is performed for the prediction and simu-

lation of complex fluid flows over aircraft. The validation of prediction and simulation methods is accomplished by means of a coordinated experimental test program. This activity also provides improved insight into the fundamentals of flow physics, as well as the detailed flow measurements required for verification of the computations. Viscous flow research is conducted with emphasis on developing specific devices and design techniques to reduce overall aircraft drag.

Numerous advanced solution algorithms have been generated for complex viscous flows, and innovative gridding techniques developed to resolve the added geometrical complexity of realistic three-dimensional configurations. These new algorithms and gridding techniques were tested for three-dimensional geometries at transonic and supersonic speeds. To assess the accuracy and reliability of these new techniques and codes, both computational studies and experimental verification activities are in progress. Significant advances have been made in the enduring problem of understanding, predicting, and modeling the onset and structure of turbulence. The Center for Turbulence Research completed a highly successful first year of operation with coordinated efforts in theoretical computational and experimental turbulence physics. Experiments were identified to be conducted to generate the data for turbulence modeling and code validation. Drag reduction flow research efforts have focused on laminar flow control, natural laminar flow concepts, and turbulent skin friction drag reduction. The development of surface geometry modifiers included research to extend proven concepts such as riblets and large eddy breakup devices to supersonic speeds. These passive friction reduction techniques have also been applied to the control of flow separation associated with shock wave/boundary layer interaction.

In FY 1990 CFD research will be directed toward development of faster and more efficient numerical algorithms to facilitate full Navier-Stokes solutions including flows with large wall curvatures and jet ejection. Improved methods will be derived for numerical simulation of aerothermodynamic flow phenomena associated with hypersonic cruise and maneuver vehicles including real-gas chemistry. Enhanced computational capabilities will be sought through development and use of advanced computer architectures and expert system concepts. Sophisticated, generic Reynolds stress turbulence models exhibiting greater flow realism and wider applicability will be generated. Research will be initiated to acquire a detailed data base for propulsive-lift flow interactions in ground effect. CFD validation investigations will produce transonic data bases necessary for validation of CFD codes simulating transports and other configurations. Increased emphasis will be provided for validating supersonic and hypersonic flow analyses.

Drag reduction research will emphasize high-speed skin friction reduction techniques. Passive and active concepts will be explored for flow control separation for drag reduction, stability improvement, and vehicle control. Fundamental flow mechanism investigations will include the study of turbulent flow coherent structures and boundary layer transition physics. Turbulent skin friction re-

duction devices, such as surface geometry modifiers, will be explored for the supersonic regime. Vorticity control concepts will be investigated for preventing flow separation. Hypersonic stability and boundary layer transition analyses will be performed to derive transition prediction techniques. CFD methods will be developed for slender bodies and highly swept wings characteristic of supersonic cruise configurations, including emphasis on interacting vortex flows, wing leading-edge radius effects, and variable camber devices. Emphasis will be placed on validation of transition methods for highly swept wings at supersonic speeds.

Applied aerodynamics research and technology

The objective of applied aerodynamics research and technology is to provide new, validated technology applicable to future U.S. military and civil aircraft from subsonic to hypersonic speeds. The approach is to conduct comprehensive ground and flight experiments involving realistic vehicle configurations and key configuration components. Such work is focused on areas expected to render major gains in advanced vehicle performance. Products include new analytical and experimental methods needed in the design process and new aerodynamic concepts. This work covers the full spectrum of civil and military air vehicles, including both rotary-wing and fixed-wing concepts, and also includes the area of aeroacoustics.

Configuration aerodynamics research identifies and analyzes innovative aerodynamic concepts. This program uses wind tunnel, water tunnel, and flight experiments to complement analytical aerodynamic developments for complex flows over aircraft components and configurations. Wing/airfoil optimization techniques were extended from subsonic and transonic speeds to the supersonic regime. Panel aerodynamic methods are tailored to analyze flows over an F-16 aircraft with tip missiles and under-the-wing fuel tanks. Advanced computational algorithms are developed for exploring vortex interactions. Cellular formation studies are underway for the derivation of separated flow control techniques.

Subsonic aerodynamic research emphasizes research on induced drag reduction and separated flow control to reduce aircraft drag and improve aircraft stability and control. Novel approaches to achieving lower induced drag are being investigated in the form of unconventional wing planform (e.g., crescent) and sheared wingtip shapes. New nonplanar wing theories and wind tunnel tests show that these new wing shapes can yield efficiencies higher than originally thought possible, based on classical planar wing theory. Flight tests are also conducted to support industry applications of spin-resistance technology to new aircraft designs.

Significant advancements have been made in recent years in the development of codes for application to the low-disk-loading rotors of conventional (e.g., helicopter and tiltrotor) and advanced rotorcraft. While the methodologies will continue to evolve, one of the most important needs for the near term is the experimental verification/validation of these methodologies. Preparations for major experimental activities have been completed, and these experiments will be the focus of the rotorcraft program over the next few years. These activities include both flight test and wind tunnel test

programs, with primary emphasis on the investigation and measurement of unsteady airloads and high-speed performance. In addition, significant activity over the next few years will be devoted to the support of new military rotorcraft programs.

The high-performance (fighter/attack) vehicle research program is focused in three key technology areas: (1) short takeoff and vertical landing (STOVL), (2) high angle-of-attack maneuverability, and (3) supersonic cruise and maneuver. In the STOVL arena, research is directed toward new powered-lift concepts for hovering; methods to predict the complex flow surrounding a hovering vehicle, especially near the ground; and investigation of flight dynamics of transition between hover and forward flight. Studies have been completed to define and the most promising STOVL vehicle concepts, and the key technologies needed are being pursued. In the area of high angle of attack, both new experimental and analytical methods are being developed for the prediction and control of the separated and vortex flows which will allow advanced, superior U.S. vehicles to push beyond the traditional stall barrier by virtue of increased stability and control. In the supersonic cruise arena, new nonlinear prediction and design methods for advanced airfoils and wing planforms are being developed to improve cruise efficiency and maneuverability of advanced fighters.

Research is performed to derive advance techniques and instrumentation for more accurate and efficient testing, both in wind tunnels and in flight, to validate the analytical methods. An adaptive wall test section has been developed and installed in the 0.3-meter transonic cryogenic wind tunnel. Wall interference-free data are being taken on advanced airfoil test sections. Instrumentation research has emphasized high-speed flow sensing to support U.S. initiatives in supersonic and hypersonic vehicles. Concepts to be investigated include infrared boundary layer transition visualization, micro-encapsulated liquid crystal methods for advanced flow visualization, and laser fluorescence for hypersonic flow sensing. Also, the development of laser velocimetry to obtain high-response measurements in supersonic shock flows is being pursued.

In the area of aeroacoustics research, work continues to determine acoustic and structural fatigue loads of supersonic heated flows (i.e., jet exhausts). Particular emphasis has been placed on determining flight effects and the effects that these high-frequency loads have on airframe and structural design for advanced aircraft.

The research program in FY 1990 will emphasize induced draft reduction and turbulent drag reduction. Induced-drag research activities will focus on wing-tip and trailing-edge geometry modifications to reduce draft due to lift. A supersonic flight test of riblets as a means to reduce turbulent skin friction will be coinducted. Flight research to determine the stability and control characteristics of sheared wing tips will be initiated. Flight tests to evaluate the handling qualities of natural laminar flow wings will be completed. Transition mode and sensor instrumentation will be evaluated in a flight research program.

Research efforts will be made to acquire a test-validated sophisticated technique for predicting three-dimensional wing flow separation. An advanced vortical flow analysis method to predict wing and wake flows at high angle-of-attack attitudes will be sought. Re-

search will be performed to acquire an improved understanding of wing/body vortical flows to include insights into vortex production and breakdown phenomena. Three-dimensional viscous flow interaction phenomena will be explored through analytical and experimental approaches.

Several major full-scale rotorcraft experimental programs will be continued. One such activity is a joint program between NASA, the U.S. Army, and industry to conduct an experimental flight investigation with a highly instrumented UH-60 Black Hawk helicopter. The performance, noise, and vibration characteristics of tiltrotor aircraft, in hover and in forward flight, will be investigated.

High-performance research in the STOVL arena will include the evaluation of advanced configurations developed under the U.S./United Kingdom program and the identification of technologies to be pursued, as well as the completion of a wind tunnel test of a large-scale advanced powered-lift fighter concept. High angle-of-attack research will continue development of analytical predictions of post-stall aerodynamics and comparison with wind tunnel and flight test angle-of-attack conditions. Supersonic research will extend the analytical modeling methods to include solution-adaptive grid refinements; applications to arbitrary, complex geometries; and the development of techniques to predict aerodynamic control surface effectiveness and the characteristics of thrust vectoring nozzles.

Efforts will be initiated for development of real-time interferometry techniques for unsteady flows. Advanced methods will be pursued for accurately sensing and handling aerodynamic flight test data, both boundary layer and off-surface flows. Measurement techniques for time-varying turbulent velocity fields will be explored. Development of three-dimensional wind tunnel adaptive wall techniques will be investigated. Wind tunnel model magnetic suspension research will be reduced in FY 1990.

Propulsion and power research and technology

The objective of the propulsion and power research and technology program is to provide the understanding of the governing physical phenomena occurring at the disciplinary, component, and subsystem levels that will support and stimulate future improvements in propulsion system performance capability, efficiency, reliability, and durability. Research is being conducted in a wide variety of subsystems with applications ranging from general aviation through the hypersonic aerospace plane. Ongoing disciplinary research on instrumentation, controls, internal fluid mechanics, and aerothermodynamic concepts is providing the foundation necessary for continued advancement at the component and subsystem level. These research efforts will lead to high-payoff propulsion system improvements which have historically provided a major share of aircraft performance advances and also enabled new classes of vehicles.

In the discipline areas, internal computational fluid mechanics continues to be an increasingly important tool for understanding flow phenomena and improved designs of aeropropulsion systems through the development of advanced algorithms and analysis methods for complex three-dimensional flows in inlets and nozzles,

turbomachinery and chemically reacting flows, including their validation with basic experiments. A two-dimensional steady viscous reacting flow code that incorporates real-gas properties and is capable of high-speed hydrogen-air combustion solutions has been completed and distributed to industry. In 1989, the reacting flow code will be extended to three-dimensions, and the initial turbulent reacting shear-layer flow data sets will be obtained for verification. In addition, a three-dimensional Navier-Stokes code will be validated for internal flow and heat transfer in inlets, ducts, and nozzles. The second area, instrumentation and control research, is aimed at developing advanced high-temperature sensors, optical nonintrusive measurement systems, and advanced engine sensors and controls for future propulsion systems. Laboratory evaluations of two nonintrusive Rayleigh scattering-based gas density and temperature measurement systems have been completed, and the most promising system will be field tested in FY 1989 to demonstrate its advantages in actual research use. A prototype fiber-optic position sensor has also successfully completed environmental testing, and the electro-optical architecture for incorporating this and other passive optical sensors in an integrated propulsion-airframe control system will be defined in FY 1989.

For subsonic transport propulsion research, the objective is to develop the fundamental technologies to improve the thermal efficiency of advanced subsonic powerplants by 20 percent. In 1989, the first year for this research activity, concept studies will be used to identify specific research needs for thermal efficiency improvement. Research will be initiated to develop a large low-speed axial turbomachinery rig which will be used to develop empirical closure models for advanced analytical methods that are an enabling technology for development of high-pressure-ratio compression systems. General aviation engine research is aimed at rotary engines with the objectives of 40 percent reduction in fuel consumption, a power density increase of 30 percent, and multifuel capability. Stratified-charge rotary engines have demonstrated multifuel capability and the goal increase in power density. Experimental verification is underway for a five percent cycle efficiency improvement achieved by eliminating wake interferences between fuel jets, as predicted by a three-dimensional model of internal air flow and fuel injection patterns.

In supersonic cruise research, the objective is to develop technology for efficient, environmentally compatible propulsion concepts for Mach 2 to 4 cruise operating conditions. During FY 1988, all hardware fabrication and facility modifications for rig testing of the supersonic throughflow fan concept were completed. Initial testing of the fan rotor will begin in late FY 1989 after facility checkout completion. The scope of research in this flight regime is also being expanded in FY 1989 to include engine cycle and configuration studies, and initiation of small-scale experiments to address two critical areas of environmental acceptability—reduction in airport noise and engine emissions. For high-performance applications, the goal is to develop propulsion systems technology for powered lift and thrust vectoring that will lead to improved aircraft short takeoff and vertical landing (STOVL) and supermaneuvering capability during flight. Principal activities during FY 1988 includ-

ed small-scale model experiments on advanced inlets and nozzle concepts, and the modification, upgrading and calibration of several research facilities for improved component flowfield measurements and analysis code validation. Planned milestones for FY 1989 include the completion of test and analysis on a short diffuser inlet, an initial block-and-turn ventral nozzle experiment, and a full-scale ejector system based on mixed-cycle primary air.

The hypersonic propulsion research objective is the development of the basic understanding of high-energy fluid phenomena, dynamic models, advanced concepts, and the diagnostic and facility technologies for high-speed cruise at Mach 4 and above. Development of the shear layer combustion facility will be completed in 1989 to study the effect of combustion on the shear layer mixing process. Experimental studies will be initiated to determine the effects of contaminants, such as water vapor and nitrogen oxide, on the supersonic combustion process.

Research emphasis in internal computational fluid mechanics will be placed on advanced prediction capabilities that are three-dimensional, viscous, and include reacting flow and heat transfer, where appropriate. The experimental data base from the large, low-speed centrifugal compressor will be used to determine the ability of a three-dimensional viscous turbomachinery code to model the important flow characteristics such as separated and secondary flows. A two-dimensional viscous turbomachinery code that characterizes such as separated and secondary flows. A two-dimensional viscous turbomachinery code that predicts heat transfer will be extended to three-dimensional and validated using the results of the compressible flow experiment that includes detailed measurements of surface heat transfers and the flowfield with a horseshoe vortex which is typically found in turbine flow passages.

Advanced instrumentation and control research will continue to focus on the development of nonintrusive optical sensors, high-temperature electronics, and the growing need and advantages of propulsion-airframe integrated controls. With respect to research instrumentation, efforts will be applied to the development of 1800-degree-Fahrenheit static strain gages, a thin-film (30-micron) heat flux gage, and limited-view gas density measurement systems using heterodyne holographic interferometry. In the controls area, hardware for the selected electro-optical architecture will be fabricated, integrated with optical engine and airframe sensors, and the combination environmentally tested to ensure function and durability.

Subsonic transport research will include the completion of the low-speed multistage flow physics facility for turbomachinery and the acquisition of the initial viscous blade row interaction experimental data base for turbomachinery code verification and closure model development. Turbine design will begin for the warm turbine rig which will be used to develop the experimental verification data base for three-dimensional viscous turbomachinery codes that include heat transfer. General aviation engine research activities will continue to focus on advancing rotary engine technology. The structural viability of a titanium lightweight rotor for improved rotary engine power density will be determined and tests initiated. Analysis of the combustion process through advanced computer modeling will guide further improvements in combustion efficiency

to enable the fuel consumption goal of 0.35 brake-specific fuel consumption.

Supersonic cruise research will continue the development of advanced propulsion concepts such as the supersonic fan and innovative turboramjet-type cycles offering improved high-speed efficiency and flight envelope expansion. Continuation of testing of the supersonic fan will include full-stage mapping (rotor plus exit stator) and use of laser anemometry measurements to define and analyze the complex flowfields. Thermal performance testing of a prototype ceramic heat exchanger will also be completed, and studies will continue with industry to define innovative components and configurations that extend the advantages of turbomachinery-based propulsion to higher Mach number capability. In the area of high-performance aircraft research, efforts will continue to concentrate on super maneuverability and STOVL technologies for future fighter aircraft. Small-scale inlet model testing at high angle of attack and analysis with more sophisticated codes will be conducted to identify critical stability issues, and the exhaust gas ingestion effects data base will be expanded to include several promising STOVL configurations through the use of a new, more flexible aircraft model and test support system.

Hypersonic propulsion activities will include fundamental experiments to provide an understanding of high-speed inlet flow physics, exhaust system flow physics and its associated flow chemistry, heat transfer experienced in internal flow systems with very high-energy flows, mixing mechanisms necessary for complete heat release, and high-speed combustion. These experiments will be guided with, and the results compared to, advanced three-dimensional flow analysis codes that have the capability to resolve separations in the flow, flow chemistry, and heat transfer rates. Successful completion of the velocity and direction, but also density and chemistry.

Materials and structures research and technology

The objectives of the materials and structures research and technology program are to: (1) develop and characterize advanced metallic, intermetallic, ceramic, polymer, and composite materials; (2) develop novel structural concepts and design methods to exploit the use of advanced materials in aircraft; (3) advance analytical and experimental methods for determining the behavior of aircraft structures in flight and ground environments; and (4) generate a research data base to promote improvements in performance, safety, and durability of aircraft, as well as reduce that weight and life cycle cost.

Research in materials is directed toward airframes and high-performance gas turbine engines. In airframe materials research, studies are being conducted in advanced materials for high-temperature applications including new thermoplastic polyimides and metal matrix composites, processing methods for superplastic forming of aluminum alloys, light alloys such as aluminum-lithium, and intermetallics. Engine materials research focuses on advanced metals, intermetallics, ceramics, fiber-toughened ceramics, and polymers.

Aircraft structures research is focused on developing innovative concepts for airframes and engines that are lightweight, durable,

and cost-effective. Primary areas of research are advanced analytical methods to predict structural response, multidisciplinary analysis and optimization to predict aerodynamic and acoustic loads and improve design methodology, understanding fatigue and fracture mechanisms to improve reliability and low-cost fabrication methods.

Research in aeroelasticity includes computational methods to predict flutter and performance of aircraft; control concepts to improve performance, enhance stability and reduce loads; and development and testing of advanced aircraft configurations. Activities are balanced between the needs of civilian aircraft to improve competitiveness and national defense needs for high-performance aircraft.

Primary areas of rotorcraft research are understanding and predicting main rotor aeromechanics, multiblade interactions, and response and control of noise surrounding and inside rotorcraft. Current emphasis is placed on advanced main rotor configurations, airborne and structureborne noise reduction, and the interactions of the helicopter main rotor with airframe dynamics.

Hypersonic research is directed toward lightweight material systems and structural concepts that can withstand the very high temperatures encountered during hypersonic flight.

Materials research will concentrate on advancing the understanding of the relationship between processing parameters, microstructure, and properties of metallic, intermetallic, ceramic, polymer, and composite materials, with primary emphasis on high-temperature applications. New and tougher organic matrix composites capable of long-term use up to 700 degrees Fahrenheit; reliable monolithic and whisker-toughened silicon-carbide and silicon-nitride, high-strength/ductile intermetallic aluminides; and fiber-reinforced aluminide composites will be developed. This will also require new and innovative composite fabrication methods. An understanding of fatigue, fracture, and time-dependent deformation behavior of light alloys and metal matrix composites at both elevated and cryogenic temperatures will be pursued. Multiaxial constitutive models for composites will be developed for prediction of environmental effects, high-temperature cyclic damage, and loading rate dependence.

Airframe structures research will continue to emphasize the mechanics and fundamental behavior of composite structures and innovative concepts for use of light metallic structures. Specifically, during FY 1990 methods for predicting and preventing failure modes in composite structures will be studied, including nonlinear behavior of buckled shells and complex three-dimensional structures and matrix interleaving to improve toughness of integrally stiffened structures. In support of subsonic aircraft, impact drop tests will be conducted on composite aircraft fuselage sections. Propulsion structures research will develop integrated structural/thermal tailoring methodology for high-temperature engine components and evaluate concepts for composite engine structures and advanced actively controlled bearing concepts.

Advanced analytical methods will be developed in the computational structural mechanics (CSM) program. CSM will focus advanced computational methods, including probabilistic analysis and

boundary elements for the structural analysis of airframes and engines, emphasizing the solution of very large, complex problems. NASA's supercomputer facility will be used to develop solution methods for very large problems while superminicomputers and highly configurable transputers will be used to develop solution schemes for various computer architectures.

The aeroelasticity research activity will develop analytical methods to predict unsteady aircraft loading using advanced Euler methods and will develop control laws to reduce the maneuver load for a flexible activity controlled wing. The effects of damping and blade mistuning will be incorporated into the analysis of counter-rotating turboprops, and research will continue to understand the aeroelastic response of supersonic flow through turbomachinery.

Interdisciplinary research will develop efficient optimization methods for coupled aero-structural design of aircraft wings and rotorcraft main rotors. In particular, to support the rotorcraft research activity, a main rotor concept optimized to reduce dynamic loading will be tested in the wind tunnel.

In hypersonic research, integrated flow-thermal/structural analysis methods will be used for accurate mission loads prediction to aid the development of lightweight, efficient, and durable airframe and propulsion systems. New materials and structural concepts will be evaluated for actively cooled hot structures. Additional efforts will focus on ceramic composites, intermetallic composites, and carbon/carbon, constitutive behavior, and oxidation-resistant and thermal barrier coatings.

Information sciences research and technology

The information sciences research and technology program will provide the fundamental capabilities to: (1) exploit advanced computer architectures to meet NASA's unique computing requirements, (2) increase the agency's ability to develop high-quality aerospace systems software, and (3) provide the advanced theory, concepts and capability to effectively use and manage aerospace information. Effective exploitation of computational modeling of physical processes, such as computational fluid dynamics (CFD), will be enabled through the developmental of fundamental understanding of the relationship between physical algorithms and advanced parallel processing architectures. Research on the theoretical foundations for managing complex software systems and on the development and validation of reliable software is directed toward improving the quality and reducing the costs of complex mission-critical software.

Parallel processors offer the potential for enabling numerical simulation at affordable costs. A prototype algorithm was implemented and tested on the connection machine. Also prototype algorithms for solving incompressible flows and for solving high-altitude transonic flows using particle tracing methods were implemented and tested. Evaluating performance of parallel processors is an important problem to both computer systems architects and application developers. A distributed operating system testbed was established to conduct performance evaluations on selected distributed operating system concepts developed under research grants. Performance prediction tools are being developed for the evalua-

tion of different concurrent architectures and in the detection of bottlenecks in hardware and software. A set of metrics which can accurately measure the performance of numerical architectures was developed. The scientist's workbench, providing a vehicle for testing advanced work station concepts, incorporated graphics super work stations capable of handling three-dimensional data and animation. The hardware prototype of the space-distributed memory was brought on line and put in use for experiments, including the testing of the text-to-speech translation problem. The University of Illinois conducted a series of research task addressing the reliability and development of complex mission-critical software. The theoretical basis for the assessment of software redundancy was extended, specifically addressing the model of coincident errors. A nonreconfigurable, fault-tolerant operating system for verifiable integrated processor for enhanced reliability (VIPER) microprocessors was specified in the enhanced hierarchical design methodology (EHDM) proof environments.

The high-speed mainframe computer networking subsystem continues to provide NASA aeronautical researchers remote access to the agency's mainframe computers. The system supports transmission rates up to 1.5 million bits per second from NASA's geographically distributed research centers.

Research on the use of novel parallel processors controlled by new algorithms for efficient numerical simulation will continue at the Research Institute for Advanced Computer Science (RIACS). Performance of special purpose CFD computers, including a systolic processor and the Navier-Stokes machine, also will be evaluated. The research will address other aerospace applications of parallel processing including computational structural dynamics and visual research. Experimentation on prototype programming environments for parallel systems and use of parallel algorithms to benchmark advanced architectures will continue. Research in sparse distributed memory, developed as a mathematical model of human long-term memory with the properties of associative recall, will continue; the theory underlying the new memory architecture will be advanced. The ultimate capability of such a memory could include computer vision and natural language. A hardware simulator will be evaluated in a number of aerospace application studies. One set of evaluations will include the study of how effectively the computer can be trained to recognize characters. A research program in networked systems to examine the interactions and underlying capabilities provided by systems of computers, experimental facilities, and humans connected by networks will be conducted. The focus is on the architecture of such distributed systems and the resulting requirements for network function and performance.

Software engineering studies will quantify the reliability gained from formal specification, software prototyping, computer-aided software engineering systems, software reuse, and formal verification. The Institute for Computer Applications in Science and Engineering will conduct research in these areas. The block grant for fundamental computer science at the Illinois Computing Laboratory for Aerospace Systems and Software at the University of Illinois will address characterization and evaluation of automated support

tools for increased reliability in software specifications and design, including Ada programs.

NASA will continue to support the operation of the computer networking system to provide for the effective and productive use of NASA's distributed computing resources. NASA will continue to work through the Federal Coordinating Council for Science, Engineering and Technology to coordinate national access to high-performance computers.

Controls and guidance research and technology

The controls and guidance research and technology program will provide a technology base supporting future aircraft designs which will be capable of safer and more efficient operation and will have greatly expanded flight envelopes. The specific objectives of the controls and guidance program are: (1) to exploit emerging controls, guidance, and artificial intelligence (AI) technologies for the development of advanced automation concepts for applications, including rotorcraft nap-of-the-Earth (NOE) flight and more efficient operations within the national airspace system; (2) development of highly reliable system architectures and validation methods for flight crucial systems; (3) development of airborne wind shear detection sensors; (4) development of advanced control, guidance and display theories, concepts and analysis methods; and (5) development of new methodologies for multidisciplinary integration.

Knowledge-based control and guidance concepts have been shown to be feasible for improving system design, performance, and crew-vehicle interface. Research culminating in flight test has demonstrated reduced development time and added in-flight capability for an aircraft system redesigned using AI techniques. Analytical methods, assessment techniques, and experimental methodologies have been developed for the evaluation and validation of fault-tolerant, concurrent processing, and distributed computer systems for aircraft applications. Multiple tools and software codes are now distributed to and are in use by industry.

Three alternate technologies for in-flight detection of wind shear are currently under investigation. The recently developed wind shear hazard index has achieved status as an industry standard. Additionally, microburst models for dynamics and structures applications have also received wide industry acceptance. As high-order dynamics become more important to aircraft performance, safety and efficiency, the integration of numerous heretofore specialized disciplines has become a critical necessity. Multidisciplinary techniques for integrating controls, guidance, propulsion, structures, and cockpit systems are being pursued. Structures and controls have been integrated into a preliminary set of control laws for an active flexible wing model now being prepared for wind tunnel testing.

Advanced air traffic flow control concepts and the integration of four dimensionally equipped aircraft into the national airspace system are under study to improve the efficiency of air traffic control (ATC) operations. Both simulation and flight tests have been performed in preparation for an upcoming operational test to be conducted with the Federal Aviation Administration at a test site to be selected in the future.

Continued analytic and systems research in nonlinear control theory, fault-tolerant systems, wind shear modeling, and advanced display concepts will be conducted. A complementary mix of near-term applications and long-term basic research will be balanced to provide focused efforts on specific milestones, while continuing research in state-of-the-art technologies. As individual areas of aircraft design, control, and propulsion become increasingly sophisticated, once minor effects and influences from other aircraft systems begin to gain importance. As a result, multidisciplinary modeling and design techniques will be emphasized as a high potential research topic.

Increased emphasis also will be placed on in-flight demonstration and test in a number of research areas, including live ATC evaluations at Denver, system component research for automated NOE flight, in-flight evaluations of alternative wind shear detection devices, and preliminary development of AI-based controls and guidance techniques for an entire transport aircraft flight control system. These tests will greatly improve the final validation of research developments and assist in timely transfer of new technology to industry users.

Human factors research and technology

The objective of the aeronautical human factors research and technology program is to provide the capability to design effective crew-cockpit interfaces and air traffic control (ATC) interfaces with the aircraft. Advanced automation technologies, along with increased traffic density, challenge human operators and their interface with diverse air and ground systems. The goal of the program is to provide human-centered technology which is safe, productive, efficient and effective for advanced commercial and military aircraft, rotorcraft, and other national aeronautical applications.

Flight management research in FY 1989 will provide new concepts for audio and visual display of potentially conflicting air traffic and recommended evasion and escape from pending collisions which is a follow-on to the earlier traffic alert and collision avoidance system (TCAS). A hybrid symbolic/neural network model has been developed and will be applied to a new pilot situation assessment and rapid decision-making aid. A prototype of a situation-adaptive crew information management system which allowed human interface with an intelligent diagnostic system was completed. Pilot acceptance tests will be completed for a three-dimensional velocity vector system which was shown on a helmet-mounted display. Simulator evaluation of wind shear adaptive guidance techniques for use in landing under severe wind shear conditions will be completed in FY 1989.

Human engineering research will lead to new physiological and behavioral workload assessment and monitoring techniques for predicting pilot performance. Tests were conducted to explore the relationship between pilots' reported level of boredom in long-haul flights and their performance as seen in physiological measurements of cortical activities. Analysis of two-person crews in long-haul, multiple time zone flights will be conducted to determine effective countermeasures to circadian desynchronization.

Research in aviation safety/automation will provide guidelines for the design and implementation of automated systems in the cockpit. Simulation and flight experiments were performed to evaluate a final approach spacing tool for ATC personnel so they could handle increased traffic in the landing phase of flight operations. New concepts for identification and display of multiple in-flight faults were identified. An automated system for monitoring crew cockpit procedures will be evaluated in 1989.

In focused rotorcraft research, several information presentation techniques for day and night flight were developed and will undergo evaluation in FY 1989. These allowed more precise flight path control and geographical orientation. A unique set of data was compiled relating to pilot error under high-stress flight conditions associated with emergency medical evacuation.

Base human factors research and technology development will continue to provide methods whereby flight crew performance will be improved and human-error opportunities reduced. Among these methods will be the following: application of three-dimensional displays for visual tracking of very precise flight paths and display of position in vertical and horizontal range of multiple aircraft; tests and verification of pilot performance enhancement due to usability of in-flight, computer-based fault detection and classification techniques; guidelines for pilot procedures to allow the crew to maintain a level of awareness under levels of low workload and low task demands; and development of rotorcraft crew procedures for visual search and visual navigation under low levels of visibility and high workload conditions.

The aviation safety/automation program will enter a phase of intensive simulation testing, experimentation, proof-of-concept demonstration, and evaluation of human-centered automation. New techniques of information exchange, management, and display in cockpits and at ATC work stations which reflect various levels of automation will be tested. Guidelines and concepts developed in FY's 1988 and 1989 from the entire human factors base program will provide a technical basis for these new interfaces between humans and automated systems. Tests of these guidelines in FY 1990 will lead to intelligent, error-tolerant or error-resistant cockpits and ATC work stations which must function safely and effectively in the future automated ATC environment. Planning activities performed in FY 1989 will be completed and implemented in updated air traffic control simulation facilities at Ames Research Center and Langley Research Center so that testing may begin. Other base research in flight management, subsonic transport, and human engineering methods will feed into this program.

Flight systems research and technology

The objective of the flight systems research and technology program is to provide the necessary research and technology development for an improved and validated base of advanced technology for application by industry to future generations of the entire spectrum of aircraft. The program is organized into the following categories: (1) aviation safety; (2) flight instrumentation and test techniques; (3) fighter/attack aircraft; and (4) flight support. The activities within this program encompass advanced engineering tech-

niques and the establishment of the feasibility of concepts to ensure rapid applications of promising new technology essential to meeting one or more of the following goals: (1) reducing aircraft accidents resulting from weather effects (heavy rain and icing); (2) improving flight efficiency, enhancing data accuracy, and enabling the acquisition of needed information; and (3) establishing a technology base for the design of future fighter aircraft with unprecedented maneuverability at high angle-of-attack (up to 90 degrees) flight conditions and vertical landing capability. Support services are provided to flight research projects using standard aircraft for chase, airspeed calibration, remotely piloted research vehicle drops, and flight crew readiness training.

The heavy rain tests using the aircraft landing dynamics facility have been completed, and the lift loss caused by heavy rain has been established for a typical airfoil section. The model helicopter rotor tests, which were conducted jointly with industry in the icing research tunnel, have been completed. Ice shape and section drag measurements have been obtained on a Twin Otter aircraft for comparison with data from the icing research tunnel. A developmental model of the airborne information management system was used in flight to measure vertical wind shear in the atmosphere. The evaluation and ranking of short takeoff and vertical landing (STOVL) propulsion concepts were completed, and the concept-specific technology development program has been defined and initiated. The baseline vortex flow characteristics have been established for the F-18 aircraft at high angle of attack by both on-surface and off-surface flow visualization. Detailed forebody and leading-edge extension (LEX) pressure distributions were also obtained for correlation with wind tunnel and computational fluid dynamics (CFD) results. Advanced CFD methods have been employed to calculate the flowfield around the forebody, LEX, and wing with excellent comparisons to the F-18 aircraft. The critical design review for the multiaxis thrust vectoring system was completed and manufacturing was initiated.

The emphasis in aviation safety will continue in the areas of advanced concepts for ice protection, improvement of the ice accretion prediction codes, acquisition of additional ice accretion physics data, development of methodologies for icing scaling, improved cloud droplet instrumentation, and flight tests to validate predictive codes and icing research tunnel results. Test data acquired from the aircraft landing dynamics facility will be analyzed to assess the aerodynamic penalties associated with heavy rain.

The F-18 high angle-of-attack research vehicle will be modified with the addition of a multiaxis thrust vectoring system to enhance maneuverability and agility. Flight research, using the F-18 high angle-of-attack research vehicle (HARV), will be conducted to investigate the potential benefits and assess the aerodynamic, propulsion system, structural, and flight control system interactions resulting from multiaxis thrust vectoring at high angles of attack. Prediction methods for high angle-of-attack aerodynamics will be validated through correlation of CFD, wind tunnel, and flight results. A national symposium is scheduled in FY 1990 to report the progress in correlating CFD and flight-measured aerodynamic results. Emphasis will be placed on the accelerated development and

understanding of critical integrated control technologies incorporating thrust vectoring to attain and control flight at post-stall conditions. Vortex control methods will be developed and evaluated in wind tunnel tests. In the STOVL program for FY 1990, the development of critical technologies identified in recent studies will be continued. These include analytical and experimental research in the areas of flow diverter valves and ducts, integrated flight/propulsion control systems and handling qualities, cruise and vertical landing nozzles, and ground environmental effects.

Development and flight evaluation of an advanced airborne information management system will continue. Flight tests and evaluation of a single-axis optical air data system will be conducted, and research will be initiated to develop a three-axis optical air data system suitable for use in flight.

Flight test support of flight research projects will continue using a variety of both fixed- and rotary-wing aircraft. These high-performance support vehicles will be flown as chase aircraft in support of research aircraft described under high-performance systems technology (X-29, F-18, F-15, F-16XL) and rotorcraft systems technology (XV-15, tiltrotor). Also included is specialized training for critical personnel, as well as maintenance of flight data facilities, aircraft instrumentation, and flight data processing.

Systems analysis

The objectives of the systems analysis effort are to identify and quantify the impact of emerging technologies in aerodynamics, materials, structures, propulsion, and systems that can lead to new plateaus or major improvements in civil or military aircraft of the future; create new markets; reduce noise and environmental impact; and provide potential new economic benefits. Conceptual designs are performed incorporating new technologies, and sensitivity analysis and trade-off studies are conducted to quantify the benefits of the emerging technologies.

In FY 1989, systems analysis for rotorcraft is concentrating on advanced configurations and propulsion systems for high-speed tiltrotors and rotorcraft. High-speed rotorcraft have the potential future application in the civil market to efficiently transport passengers between the city centers and remote airports and, in the military market, to transport both troops and equipment to remote battle locations and to perform air combat missions. Computer conceptual design codes are being improved so that the benefits of new technologies to alternative high-speed rotorcraft configurations can be quantified.

The high-speed civil transportation studies with the two major airframe manufacturers will be completed in FY 1990. This effort is identifying the most promising vehicle and propulsion system concepts for future high-speed civil transportation. The preliminary results seem to indicate that commercial supersonic passenger transportation could be environmentally compatible and economically viable with aggressive development of advanced technologies. In-house studies are also being performed in the following areas: sonic boom, community noise, environmental impact, airframe/propulsion integration, and fuels. In FY 1989, the concept feasibility is being investigated and potential benefits assessed for a supersonic

throughflow engine capable of powering a supersonic transport. The concept has the potential of a 12 percent efficiency improvement over a conventional turbofan engine for this application.

Systems analysis for high-performance aircraft in FY 1989 focuses on advanced short takeoff and vertical landing (ASTOVL) aircraft. As part of a cooperative U.S./United Kingdom program, five configurations developed by contractual studies have been evaluated, and the down-selection is in process. The focus for the technology development will be on configuration-specific technologies.

In FY 1990, studies will be performed on a wide variety of innovative propulsion systems that offer potential revolutionary improvements in aircraft capabilities. These analytical investigations will explore many alternative concepts and advanced technologies to identify the most promising areas of future propulsion research. Preliminary design studies will be completed on very high-pressure-ratio, ultra-high bypass ratio turbofan engines which could lead to a new generation of fuel-efficient, long-range subsonic transport powerplants. Exploratory evaluations of convertible engine concepts that could enable unconventional high-speed rotorcraft concepts will also be conducted. Analyses of candidate supersonic cruise propulsion systems will continue with emphasis on propulsion system integration with the aircraft and definition of a supersonic throughflow engine configuration. In-depth analysis of several of the most promising futuristic concepts, including beam power and superconductivity, will be conducted. Development of a NASA-wide integrated engine/airframe analysis system will be pursued with the emphasis shifting toward the incorporation of multivariate optimization, expert systems, and parallel processing features.

Systems studies for rotorcraft will continue to focus on the high-speed regime. Four contracted studies with the rotorcraft industry will be continued. These studies will provide an information base for long-range planning and a focus for research and technology programs performed by NASA and the U.S. rotorcraft industry. These system studies will assess the impact of new technologies on promising high-speed rotorcraft configurations and define future technology development requirements. Efficient high-speed rotorcraft could enhance our civil transportation system effectiveness by helping alleviate problems of air and ground congestion and enable new combat strategies and military missions. Computer codes used in the conceptual design process will be updated to enable analysis of the performance, weight, cost, and other characteristics.

The in-house systems analysis efforts will concentrate on assessing the barrier issues to high-speed commercial flight including airport noise, sonic boom, and the impact of high-speed civil transport emissions on the Earth's atmosphere. Atmospheric models will be utilized to determine the impact of aircraft emissions on the Earth's atmospheric ozone layer. Also, studies will address engine cycle and exhaust nozzle noise suppression concepts for reducing community noise. Wind tunnel testing of low boom configurations will be conducted to assess the potential of innovative aircraft configurations to reduce sonic boom over pressure levels. In conjunction with these activities, research is being conducted to determine the human response to sonic boom over-pressures and signature

characteristics to identify the levels necessary for acceptable supersonic overland flight.

In FY 1990, high-performance aircraft systems analysis will focus on developing the knowledge base to effectively utilize emerging technologies to enhance fighter aircraft capabilities and to develop advanced configurations that maximize payoffs of advanced technologies. Emphasis will continue to be on supersonic short takeoff and vertical landing fighter aircraft. Studies will continue to assess the benefits of thrust vectoring control to aircraft maneuverability.

SYSTEMS TECHNOLOGY PROGRAM

FY 1990 BUDGET REQUEST \$127,100,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Materials and structures systems technology.....	\$19,200,000	\$30,300,000
Rotorcraft systems technology.....	4,800	4,900
High-performance aircraft systems technology.....	11,000	34,900
Advanced propulsion systems technology.....	13,952	14,500
Numerical aerodynamic simulation.....	39,685	42,500
Total	88,637,000	127,100,000

Materials and structures systems technology

The objective of the materials and structures systems technology program is to develop advanced materials and structural concept for future advanced aircraft propulsion systems and primary structures.

The objective of the advanced high-temperature engine materials technology program is to develop the technology for revolutionary advances in materials to enable the development of 21st century transport aircraft propulsion systems having greatly decreased specific fuel consumption, reduced direct operating costs, improved reliability, and extended life. This will require very high thrust-to-weight (20 to 1) gas turbine engines with durable, long-life, hot-section components which can endure sustained operation without cooling air. Key to these applications are materials capable of operating at much higher temperature and strength levels than now possible. Materials currently in use, such as titanium alloys and nickel-based superalloys, offer only minor potential gains in performance. The candidate advanced materials include ceramic matrix composites, metal matrix composites, intermetallic matrix composites, and polymer matrix composites. These materials are vital to attaining higher turbine inlet temperature for sustained supersonic cruise, higher thrust-to-weight engines for advanced high-performance concepts, and engine hot-section components without cooling air for greater efficiency. In addition, analytical codes to design, predict life, and establish failure mechanisms will

be developed to enable effective utilization of these new classes of materials by engine manufacturers.

The objective of the advanced composite materials systems technology program is to develop advanced materials and innovative structural concepts to fully exploit the benefits of composite materials for cost-effective primary structures for future aircraft applications. The program objectives will be accomplished through materials development, design and fabrication of innovative structural concepts, structural analysis and improved life prediction methods, and demonstration of improved structural performance through subscale and full-scale tests of critical components representative of advanced composite airframe structures. Composite replacements for conventional metallic structures have demonstrated that organic matrix composites can reduce airframe structural weight for primary structures on fighter aircraft and helicopters, as well as medium primary and secondary structures on transport aircraft. Thus, this program will focus on developing advanced toughened thermoset and thermoplastic composite materials; new structural concepts using cost-effective fabrication techniques such as advanced thermoforming, multidirectional weaving, pultrusion, filament winding and advanced fiber placement techniques, analysis, design and test methodologies to validate structural concepts; and analysis of failure mechanisms and methods for extending subscale laboratory tests to prediction of full-scale composite structural performance.

For FY 1990, advanced high-temperature engine materials research will emphasize fiber development, composite mechanics, and interfaces. Strong, stiff lightweight reinforcement fibers which are capable of maintaining chemical stability and mechanical properties at elevated temperatures are a central issue to this entire program. Research will be pursued to develop silicon-carbide, alumina, and beryllide fibers to reinforce both ceramic and metal matrices. Studies to synthesize matrix resins for polymer matrix composites will be carried out. The mechanical behavior and failure mechanisms of composite materials under the combined influences of stress (both static and cyclic) and elevated-temperature environment are highly complex and incompletely understood. Work will be pursued at both the micro- and macro-mechanical levels. Time, dependent, visco-elastic effects, such as creep and creep-fatigue interactions, will be included. New concepts in damage mechanics will be pursued, including both analytical and experimental approaches. Fundamental understanding of elevated-temperature interface behavior under severe oxidizing conditions in metal, intermetallic, and ceramic matrix composites will be pursued. Mechanical testing and environmental durability testing capabilities will be developed for temperatures to 3000 degrees Fahrenheit and above.

During FY 1990, advanced composite materials and structures research will focus on developing fundamental technology for application of composites to primary airframe structures. This research will be directed toward exploiting new organic composite materials for use up to 600 degrees Fahrenheit and toward advanced processing and fabrication concepts for low-cost composite structures. Advanced analysis methods, including probabilistic modeling of com-

posites for improved life prediction and analysis of composite failure mechanisms, will provide essential components of the technology required for the full use of composite materials in advanced aircraft. Advanced structural concepts will be developed and demonstrated in the laboratory for wing and fuselage primary structure using new composite materials and will include in-house structural test validation to provide the confidence essential for use of composite materials in future aircraft systems.

Rotorcraft systems technology

The rotorcraft systems technology program is significantly increasing high-speed rotorcraft research, particularly for promising opportunities for tiltrotor aircraft.

In 1989, the program is focused on noise and tiltrotor flight research. The NASA-developed comprehensive noise prediction code called ROTONET will be validated with industry to meet the prediction accuracy goal of 1.5 decibels. To meet a goal of 80 percent noise reduction, a radical platform concept is being tested in small scale, and a low-noise airfoil will be tested in full scale.

In preparation for increased high-speed rotorcraft research, tiltrotor noise is being measured and the results analyzed to determine abatement profiles for civil operation and to address detection for military use. In addition, advanced composite blades for the XV-15 tiltrotor research aircraft are in flight testing to evaluate their promise for increased maneuverability, performance, and reduced noise. Pressure-instrumented versions of these blades are being designed for future tests to understand basic aeromechanics phenomena.

In noise technology, far-field propagation and detection prediction are two acoustics issues to be investigated for military use. Validation of ROTONET for new concepts will continue. In the high-speed rotorcraft area, the pressure-instrumented tiltrotor blade will be fabricated for wind tunnel and flight testing use. Increased emphasis on technologies necessary for high-speed rotorcraft will include wind tunnel investigation of the potential for active control and application of advanced computational techniques to the alleviation of tiltrotor download. Cooperative research will continue with the Navy for V-22 tiltrotor technology assistance.

HIGH-PERFORMANCE AIRCRAFT SYSTEMS TECHNOLOGY

	1989 current estimate	1990 budget request
High-performance flight research	\$11,000,000	\$9,900,000
High-speed research		25,000,000
Total	11,000,000	34,900,000

The objective of the high-performance aircraft systems technology program is to generate validated engineering methods and design data applicable to the development of advanced high-performance, high-speed aircraft applications. The program objectives are accomplished by analysis, ground-based simulations, wind

tunnel experimental research, and flight research involving tests of advanced aircraft concepts and systems.

The F-18 high angle-of-attack research vehicle has been extensively instrumented with the goal of obtaining a flight-validated data base for the design of highly agile aircraft. Initial flight tests have provided high angle-of-attack aerodynamic data for correlation with wind tunnel and computational fluid dynamics calculations. In the NASA/Air Force F-111 mission adaptive wing (MAW) program, aircraft performance flights with both the manual and automatic control modes of the wing system have been completed. Results have been presented to the industry and user communities. The F-15 highly integrated digital electronics control (HIDEC) project, which builds on the capability developed during the digital electronic engine control (DEEC), F-100 engine model derivative, and adaptive engine control systems (ADECS) programs, has completed an assessment of advanced trajectory guidance and control algorithms and an evaluation of the maintenance diagnostic software to be used in the self-repairing flight control system tests. The F-106 vortex flap flight experiment has been completed, and the assessment of the predicted improvements in takeoff, landing, and maneuvering performance has been completed. The flight research program utilizing the first X-29 aircraft has been completed, and criteria for wing divergence and flight control systems for highly unstable aircraft have been validated and the performance benefits of the forward-swept wing were established. The second X-29 aircraft has been delivered to NASA and flight tests have begun to assess the high angle-of-attack characteristics of the unique forward-swept wing configuration. Two F-16XL aircraft were obtained from the Air Force, and exploratory research has been initiated to assess the feasibility of achieving significant laminar flow on highly swept wings of civil and military aircraft at supersonic speeds.

The flight research activity in FY 1990 will involve several high-performance aircraft tests designed to investigate advanced concepts. The F-18, modified with thrust turning vanes to enhance agility at high angle-of-attack, will be flown to evaluate the vanes' effectiveness. The assessment and characterization of X-29 forward-swept wing performance, flying qualities, and maneuverability at high angles of attack will be completed in FY 1990. Flight evaluation of a performance-seeking control system, including hardware and software, that will enhance performance improvements already demonstrated by the F-15 HIDEC, will be initiated. Flight tests of a self-repairing flight control system design, developed jointly with the Air Force to improve system failure detection and reliability, will be completed on the F-15 aircraft during this period. Computational design tools will be utilized to design supersonic laminar flow experiments which will be tested and evaluated on the F-16XL aircraft. The flight data will be used to improve and validate these tools. Flight research utilizing a YAV-8B Harrier, modified with a full authority digital electronic control system, will be initiated to investigate a broad range of flight propulsion control integration issues for short takeoff and vertical landing (STOVL) aircraft.

The high-speed research effort in 1990 covers focused efforts addressing the critical barrier environmental issues inhibiting the potential future development of an environmentally compatible high-speed civil transport. These environmental issues include the ability to satisfy atmospheric ozone depletion concerns, meet future airport noise requirements, and reduce sonic boom levels sufficiently for acceptable overland flight. The atmospheric ozone research addressed in this program involves two elements: long-term atmospheric chemistry assessment and low-emission combustor research. The long-term atmospheric chemistry assessment will use sophisticated three-dimensional atmospheric particle transport models to calculate the projected exhaust product distribution over time. These models will be used to analyze alternative fleets of high-speed aircraft with alternative operational flight profiles and levels of aircraft and engine technology. The projected exhaust product distribution will be used as input to complex two-dimensional atmospheric chemistry models to analyze the long-term effects on stratospheric ozone. In parallel with this effort, the low-emission combustor research will develop and test alternative methods for reducing or eliminating engine exhaust products that cause ozone depletion. The primary focus is to develop advanced technology combustor designs for low nitric-oxide emissions. The airport noise reduction research addressed in this program involves research on alternative engine cycles and jet noise suppression aimed at providing the technology for meeting Federal Air Regulation (FAR) 36 Stage 3 noise levels, the same levels achieved by the quietest subsonic aircraft. This research will include airport noise calculations to examine projected levels for alternative aircraft and engine systems and anechoic chamber tests of advanced technology jet noise suppressor designs. The sonic boom reduction research addressed in this program includes aircraft configuration research aimed at reducing the sonic boom levels combined with human response evaluations to define the criteria for acceptability. The aircraft configuration research includes design analyses and wind tunnel testing of low sonic boom configurations, analysis and flight research on supersonic laminar flow control, and selected flight research efforts to verify the analyses and wind tunnel test results and evaluate atmospheric propagation effects and operational procedures.

ADVANCED PROPULSION SYSTEMS TECHNOLOGY

	1989 current estimate	1990 budget request
Advanced turboprop systems	\$11,252,000	\$11,700,000
General aviation/commuter engine technology	2,700,000	2,800,000
Total	13,952,000	14,500,000

The objective of the advanced propulsion systems technology program is to explore and exploit advanced technology concepts for future aircraft propulsion systems in high-payoff areas through the focusing of fundamental research and technology efforts and integration of advanced propulsion components.

Activities in the advanced turboprop systems program are devoted to establishing concept feasibility and providing the broad research and technology analytical and experimental data base necessary for achieving the concept's full potential. The Lewis Research Center and the NASA/industry advanced turboprop team received the prestigious 1987 Collier Trophy for "developing advanced turboprop propulsion technology for new fuel-efficient subsonic aircraft propulsion systems." Flight tests of the nine-foot-diameter large-scale advanced propeller on the propfan test assessment (PTA) aircraft have been completed. The verified large scale propeller structural, aeroelastic, and acoustic performance and provided the first controlled data set for aircraft en route noise. In addition, an advanced cabin treatment evaluation, near the end of the flight test, proved the potential of using tuned resonators as a lightweight treatment approach for low-noise cabins in turboprop-powered aircraft. In 1989, the aircraft will be used to obtain steady and unsteady propeller blade surface pressure measurements for code validation, as well as to extend the en route noise data base in cooperation with the Federal Aviation Administration. Research will also continue on cabin environment in the areas of airborne and structureborne noise contributions to the cabin and lightweight cabin treatments. Analytical and experimental installation aerodynamics research will be continued with the completion of a Euler installation aerodynamics code and the associated experimental data base.

In the general aviation/commuter engine systems technology program, the objectives are to raise the performance level of small turbine engines to approximately that of large transport turbine engines with a decrease in fuel consumption of 30 percent. The work is focused on providing a detailed understanding of the design parameters that affect component performance through the development of analytical codes and the associated experimental data base for verification. An experimental evaluation of a compact radial inflow turbine has shown the potential for reduced turbine length with improved efficiency. Preparations are underway for experimental evaluation of cooled radial inflow turbines and uncooled composite combustor liner materials.

In FY 1990, the emphasis in advanced turboprop systems research will be propeller source noise, cabin environment, turboprop/airframe installation aerodynamics, the evaluation of advanced propeller concepts, and the development of improved aerodynamic and structural analysis techniques for both single- and counter-rotation propellers. Aerodynamic and aeroacoustic analysis will be improved to better predict the results obtained during the propfan flight tests and to predict the effect of a leading-edge/tip-vortex flowfield recently discovered at off-design conditions such as takeoff. Airborne noise transmission codes will be validated for wing- and aft-mount configurations using a combination of laboratory and industry flight experimental results. Increased emphasis will be placed on active noise control research as an alternate approach for lightweight cabin treatment. Turboprop/airframe installation aerodynamics code validation will be accelerated to obtain detailed wind tunnel experimental flow data for both complete aircraft configurations and with isolated nacelle/wing combinations.

Advanced propeller concepts to be investigated both analytically and experimentally include increased sweep (made possible by improved analytical codes and materials), forward sweep for counter-rotation, and configurations for increased cruise speed to Mach 0.9.

The general aviation/commuter engine technology effort will continue to demonstrate component improvements through the practical application of validated analysis codes that will enable high-performance small engine systems. Application of ceramics to combustor and turbine components, cooling techniques for small radial rotors, and complete field surveys of a 4:1 pressure ratio centrifugal compressor for code validation will be emphasized in 1990.

NUMERICAL AERODYNAMIC SIMULATION

	1989 current estimate	1990 budget request
Numerical aerodynamic simulation	\$25,927,000	\$28,500,000
NAS operations.....	13,758,000	14,000,000
Total	39,685,000	42,500,000

The numerical aerodynamic simulation (NAS) program objective is to significantly augment the nation's capabilities in computational fluid dynamics (CFD) and other areas of computational physics by developing a preeminent capability for numerical simulation of aerodynamic flows. Ongoing research and technology base efforts in computational aerodynamics will benefit significantly from the advanced computational capabilities to be provided by the NAS program. This program will provide the computational capabilities required to obtain solutions to problems which are currently intractable. The combination of these programs will provide pathfinding aeronautical research for the future, allowing solutions of the full Navier-Stokes equations and enabling the prediction of performance of complex aircraft geometries. To meet this goal, the NAS program is pursuing the following objectives: (1) acquire pathfinding, state-of-the-art, high-speed processors; (2) provide a uniform, user-friendly system with equivalent capabilities for local and remote users; (3) provide an auxiliary processing center for secure processing; (4) investigate and incorporate parallel architecture machines into future generations of the NAS; (5) provide a hardware and software development environment for prototyping and testing of computers, networks, storage devices workstations, and graphic output devices; and (6) continue research and development of an increasingly sophisticated system of hardware/software tools and environment to assist the user in performing CFD tasks and to improve productivity.

Since NAS is both a development and operational system, two high-speed processors are necessary. The first high-speed processor (HSP-1), a Cray 2 supercomputer, has been integrated into the system in the NAS facility. The second high-speed processor (HSP-2), a Cray YMP supercomputer, was acquired and delivered in the last quarter of FY 1988. The first processor will be devoted exclusively to production computing. The second, newer and more powerful processor, will be integrated into the system while software

for production use is being developed. The original NAS Cray 2 supercomputer has been dedicated for use in the auxiliary processing center for classified processing. When a new supercomputer is available with over four times the performance of HSP-2, that machine will be acquired as HSP-3. When HSP-3 is fully integrated into the NAS system, HSP-1 will be removed to make room for more advanced processors.

The NAS system provides a UNIX operating system on all levels of the system from the supercomputer to the work station. With high-speed communication links, remote users are provided an environment which is equal to local, on-site users. The NAS system is currently supporting over 1,000 users on 335 projects at over 100 sites.

An applied research and advanced development program has been initiated to support the pathfinding goal for NAS. As part of this program, an advanced development laboratory, an advanced architecture study, and a CFD workbench project have been formed. This program will provide the capability to evaluate commercial products, to provide industry with requirements for future productions and to design new systems and software to support new architecture machines.

FY 1990 will be an important year in the development of the NAS system. The acquisition of the third high-speed processor will be initiated. With the second processor integrated into the system, the number of users and projects supported by NAS will increase accordingly. Support processing will be upgraded to satisfy the additional requirements of the system. To meet the challenge of providing one tera floating point operations (TFLOP) computing capability by the year 2000, a high parallel testbed facility will be established for the development and demonstration of highly parallel computer technologies, including architectures, algorithms, and system software.

TRANSATMOSPHERIC RESEARCH AND TECHNOLOGY

FY 1990 BUDGET REQUEST \$127,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Transatmospheric research and technology	\$69,400,000	\$127,000,000
Total	69,400,000	127,000,000

The transatmospheric research and technology program is a portion of the joint NASA/Department of Defense (DOD) National Aero-Space Plane (NASP) program. FY 1990 is the last year in the NASP Phase 2 program plan and will establish the technology base for the decision in the last quarter of calendar year 1990 as to whether to proceed to Phase 3 which is the design, construction, and flight testing of the X-30. Activities in this last year of Phase 2

(FY 1990) are directed toward completion of all contracted and technology maturation tasks now underway and toward providing the plan for the X-30 procurement and testing. There will be special emphasis on testing of components and hardware acquired earlier in the program, with extensive test programs to be accomplished in a variety of NASA and many other government- and contractor-owned facilities. There will be a concentrated effort to complete the computational fluid dynamics (CFD) design methods and analysis programs that have been developed and evaluated in the conduct of the Phase 2 program. Each of the contractors and the government design team will provide a risk assessment and complete an independent assessment of the technologies and their integration into vehicle concepts that will satisfy the NASP program goal of a reusable, hydrogen-fueled, airbreathing, horizontal takeoff and landing, aerospace plan with single-stage-to-orbit capability.

In the contracted portion of the NASP program, three airframe contractors (General Dynamics, McDonnell-Douglas, and Rockwell International) will each complete contractually-mandated design, fabrication, and thermal and loads testing of a cooled wing leading edge section, a large wing-fuselage juncture structural section, and an insulated, 1,000-pound liquid hydrogen tank-fuselage test section. The design, analysis, and test results of these component activities, and data available from the technology maturation program, along with the vehicle concept definition activities integrating each engine concept will provide the basis for each airframe contractor's X-30 vehicle proposal submission in October 1990. Both engine contractors (Pratt & Whitney and Rocketdyne) will complete all component testing, accomplish construction of the contractually-required large-scale, proof-of-concept of their engine cycle, and will conduct an extensive test program through Mach 8 simulation of pressure and temperature in one of the two vitiated, continuous flow, government-furnished engine test facilities (ETF) on the west coast at the Marquardt Corporation and Aerojet General Corporation. The results of these large-scale, steady-state test activities, taken together with all other data available from the technology maturation program, will provide the basis for the X-30 engine proposals in October 1990.

The technology maturation portion of the NASP program, which is a large array of high-risk, enabling technology tasks in selected discipline areas, will be completed and the data and results distributed and disseminated to the U.S. aerospace industry. The Innovative Industry Materials Consortium in advanced high-temperature materials technology is a major (\$145 million) activity within the technology maturation program. The results will include characterization of advanced carbon-carbon with coatings and reduced weight; titanium-aluminide alloy characterization and various fiber reinforcement systems; several new alloy processes for high-temperature, creep-resistant applications, particularly for regeneratively cooled engine structural applications; and a major effort directed at materials formulations with reduced sensitivity to hydrogen embrittlement.

Completion of the technology maturation CFD activities will yield the largest concentrated effort in high Mach number flow

analysis and wind tunnel verification since design of the shuttle in the early 1970's. CFR methods will provide extensive three-dimensional analysis capabilities for both internal and external flows and, for the first time, "real gas" effects at flow conditions above Mach 12.

Efforts in scramjet combustor flow analysis and fundamentals, along with precision high-rate instrumentation and measurements, provide computational and experimental work in the physical and chemical processes that occur in and control the performance of this engine concept. Work in lower speed (Mach 0 to 6) propulsion systems addresses component performance and component/vehicle integration. Variable geometry inlet concepts and forebody flow-field effects on engine performance have been analyzed, and experimental testing will be completed on several different configurations in FY 1990. Unconventional nozzle configurations and afterbody shapes/contours have been analyzed, and testing will be completed. Performance/penalty tradeoffs over the operating Mach number range of the vehicle will be reported.

Hypersonic aerodynamics experiments over the full operating range (Mach numbers 0 to 25) for a variety of vehicle configurations will be completed and reported. In addition, a major effort in the theory, analysis and experimental measurement of laminar to turbulent boundary layer transition will be completed. This work, providing, design criteria for both generic vehicle drag prediction and heat transfer at hypersonic speeds, is being accomplished at NASA Langley utilizing the available low disturbance wind tunnel facilities. These data are required by the NASP contractors for the accurate and consistent prediction of the engine and airframe performance in the X-30 design proposals.

Slush hydrogen is a mixture of solid and liquid hydrogen. Its characterization and thermal management tasks are also being addressed in the technology maturation program. The potential of increased thermal capacity and increased density represents major technological improvements for hypersonic vehicle systems. Flow analysis, production, and storage methods for both ground and airborne systems are being studied and tested in governmental and contractor facilities. These data will be incorporated into the X-30 vehicle design and performance assessments during proposal development.

SPACE RESEARCH AND TECHNOLOGY

FY 1990 BUDGET REQUEST \$338,100,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Research and technology base	\$134,100,000	\$130,100,000
Civil space technology initiative (CSTI) program.....	121,800,000	144,500,000
Pathfinder program	40,000,000	47,300,000
In-space experiments technology program		16,200,000
Total	295,900,000	338,100,000

The overall goal of the space research and technology program is to provide advanced, enabling technologies, validated at a level suitable for user-readiness, for future space missions in order to ensure continued U.S. leadership in space to meet national needs. To achieve this goal, a commitment is required to provide a broad base of advanced technology for vehicle and subsystems concepts, components, devices, and software; to develop technology strengths in the engineering disciplines within NASA, industry, and academia; and to perform critical technology demonstrations that facilitate the transfer of new technology with a high level of confidence to future space missions.

The space research and technology program consists of two basic program areas, the research and technology base and focused programs. The objective of the research and technology base program is to gain a fuller knowledge and understanding of the fundamental aspects of phenomena and observables in critical disciplines. Within the research and technology base program, high leverage technological advances and concepts are brought to the level of demonstrating proof of principle. The base program is the seedbed for generating the more highly mission-focused technology programs.

Focused programs, designed and implemented based on requirements provided by the potential users of the technology, develop technology for specific applications and deliver products in the form of proven hardware, software, and design techniques and data. Two focused programs are currently underway, the Civil Space Technology Initiative (CSTI) and Pathfinder. The CSTI program is a positive first step to strengthen the agency's technical base and provide options for future low Earth orbit high-priority civil space goals. CSTI is developing technologies to enable efficient, reliable access to Earth orbit; enhance operations in low Earth orbit; and increase the effectiveness of science missions from low Earth orbit. The Pathfinder program, an element of the new national space policy, is developing critical capabilities to enable potential future missions, both human and robotic, to expand human presence and activities beyond Earth's orbit into the solar system. It will push U.S. technology forward through a strong partnership between NASA, industry and universities. Proof-of-concept testing for mission-critical engineering designs will be an important product of the CSTI and Pathfinder programs and will directly support the continuing evolution and maturation of mission plans.

In FY 1990, the research and technology base program will continue to explore newly emerging areas that offer longer range, high-leverage program benefits. The base program consists of ten discipline elements: aerothermodynamics, space energy conversion, propulsion, materials and structures, space data and communications, information sciences, controls and guidance, human factors, space flight, and systems analysis. In addition, the university space research program, supported by the research and technology base, will continue to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program. The space research and technology program will continue to support the planned research and development activities of the two ongoing focused programs, CSTI and

Pathfinder, and will be augmented to initiate the In-space Technology Experiments (INSTEP) program.

The objectives of the CSTI program are focused on research in three broad categories—transportation, operations, and science technology. The research is targeted at opportunities with clearly defined end objectives to validate technology advances. Specific program elements are: automation and robotics, propulsion, power, information technology, large structures and control, and vehicle technology.

The Pathfinder program, begun in FY 1989, will develop a broad set of technologies to enable potential future robotic or manned solar system exploration missions. The Pathfinder program is divided into five major thrusts: surface exploration, in-space operations, humans in space, space transfer vehicles, and mission studies.

The In-Space Experiments Technology program is an important new program designed to provide validated, advanced space technologies to the designers for improving the effectiveness and efficiency of current space systems and to provide major advancements for future systems. Previous efforts over the past few years have identified advanced, highly innovative technology concepts that require testing or validation in the actual space environment in order to reduce the risk to the potential users, to increase the rate of transfer of advanced technologies into future space missions, and to begin to prepare for conducting technology experiments using Space Station Freedom.

RESEARCH AND TECHNOLOGY BASE

FY 1990 BUDGET REQUEST \$130,100,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Aerothermodynamics research and technology.....	\$10,900,000	\$10,500,000
Space energy conversion research and technology	13,800,000	12,900,000
Propulsion research and technology.....	16,600,000	15,200,000
Materials and structures research and technology	20,000,000	21,600,000
Space data and communications research and technology.....	9,300,000	8,800,000
Information sciences research and technology	7,700,000	7,500,000
Controls and guidance research and technology	6,700,000	5,600,000
Human factors research and technology	5,300,000	4,600,000
Space flight research and technology	20,600,000	19,400,000
Systems analysis.....	6,900,000	6,900,000
University space research.....	16,300,000	17,100,000
Total	134,100,000	130,100,000

Aerothermodynamics research and technology

Future aerospace vehicles, such as aeroassist space transfer vehicles (ASTV), aerospace planes, and hypersonic cruise and maneuver vehicles, must be capable of sustained hypervelocity flight in both

rarefield and continuum flow regimes. The design of these vehicles presents formidable challenges to current prediction methodologies. To meet these challenges, the aerothermodynamics program is pursuing the following objectives: (1) development and application of advanced computational methods and numerical techniques covering the entire spectrum of continuum, transitional, and rarefied flows; (2) development of accurate and detailed real-gas chemistry and high-speed turbulent flow models and the efficient integration of these models with standard computational flow codes; (3) establishment of a high-quality ground and flight experimental data base for code validation and verification; (4) direct correlation and comparison of computations with available ground and flight data; (5) establishment of a detailed aerothermal loads data base and development of fully integrated analysis techniques; and (6) enhancement of engineering design codes and advanced configuration analysis capability to support rapid evaluation of future vehicle/mission concepts.

Progress continues to be made in the development of computational fluid dynamics (CFD) codes for simulating hypervelocity rarefied flowfields. In addition to the ongoing work with the direct simulation Monte Carlo techniques, a newly developed, highly efficient particle kinetic simulation scheme—which is based on new algorithm concepts using massive high-speed computer memory and higher order molecular collision models—is being developed to simulate high-altitude, low-density nonequilibrium hypersonic flows of diatomic gases. These schemes will be pushed through the transition regime toward the continuum regime.

In addition to the development of these particle kinetic simulation schemes, new efficient schemes for low-density hypersonic flows in thermochemical nonequilibrium are being developed. These schemes use newly developed constitutive relations and slip conditions that will permit extension of continuum-based methodologies for real-gas Navier-Stokes simulation into the rarefied regime.

Numerical flowfield simulations for the aeroassist flight experiment (AFE) continue to provide data bases to support the structural loads, aerodynamics, aerothermodynamics, and science requirements for design and operational purposes. Full-body AFE flowfields have been developed at both wind tunnel and AFE flight conditions to help highlight real-gas effects on the flowfield and design parameters.

Complementary to the development of computational fluid dynamics (CFD) codes and numerical simulation capability is the requirement to establish a high-quality aerothermodynamics experimental data base applicable to a wide range of vehicles and flow conditions. In addition to the aerodynamics and aerothermodynamics data base being developed in conventional wind tunnels, data are being obtained from ballistic ranges, shock tubes, and high-velocity flight programs for use in validating CFD codes with real-gas features.

The FY 1990 program in computational methods will continue to emphasize techniques for efficient coupling of real-gas chemistry models to Navier-Stokes flowfield codes. This will involve the development of more sophisticated chemistry models—based on compu-

tational chemistry results—and more robust and computationally efficient solution algorithms. Work will also continue on the development of user-friendly adaptive grid generation techniques, which can be applied to a variety of flowfields and configurations. These improved capabilities will permit more accurate simulation of continuum flow around advanced space transportation vehicles under both ascent and entry conditions.

In the area of direct simulation techniques, the focus will continue on developing the highly efficient particle kinetic simulation method. Results from this method will be compared with benchmark results from the more computationally intensive Monte Carlo method to determine the range of application for the more efficient particle kinetic simulation method. The particle kinetic simulation holds great promise for enabling rapid parametric studies of maneuvering vehicles in the upper atmosphere.

Expansion of the current aerothermodynamic experimental data base will continue, with emphasis being given to experiments aimed at code calibration and validation. Specifically, experiments will be aimed at providing nonequilibrium flows around a variety of configurations. To this end, use of NASA's high-enthalpy/high-velocity ballistic ranges and shock tubes will be increased and the development of nonintrusive diagnostic measurement techniques for hypersonic flow will be actively pursued to enable realistic hypersonic experimentation in ground facilities.

Space energy conversion research and technology

The objective of this program is to develop technology alternatives that improve performance, reliability, and cost effectiveness of space power for manned space operations, as well as autonomous Earth-orbiting and planetary exploration spacecraft. To meet the challenge, improvements of a factor of two to five and increased life potential are being sought in alternative solar power generation components, chemical energy conversion systems, energy storage systems, electrical power management and distribution, as well as the thermal management systems. For spacecraft photovoltaic technologies, the goal is to improve the total system performance enough to permit a 50 percent increase in payload mass, while not increasing the spacecraft overall mass. For environmental control and life support systems, the goal is to provide a technology base in chemical processing techniques to support future human space missions.

Recent developments in the photovoltaic (solar power) area include a 22 percent efficient gallium arsenide concentrator solar cell, testing of radiation-resistant indium phosphide solar cells, and a twofold improvement in solar panel specific power to over 130 watts per kilogram.

NASA's Lewis Research Center received a "Research & Development 100" award for demonstrating long-lived nickel-hydrogen battery performance for low Earth orbit applications. This battery, which has about ten times the cycle lifetime of existing flight systems, will be used on Space Station Freedom and on the Hubble Space Telescope. Research on advanced rechargeable batteries, such as lithium-titanium-disulfide, has demonstrated in laboratory-

scale tests the potential for achieving 80 watt hours per kilogram which is about four times current capabilities.

Advanced solar dynamic concentrator technology with 25 percent of the mass per unit area of those under consideration for future use on the Space Station Freedom has been demonstrated, and receiver concepts with one-half the mass of those proposed for Space Station have been identified.

For spacecraft photovoltaic technologies, functional testing will be completed on a lightweight prototype wing involving 12 panels with the long-term goal of having a solar array with 300 watts per kilogram that can withstand launch and on-orbit environments. Such specific power is about five times better than the best that has been flown. Research will continue on developing 20 percent efficient indium-phosphide solar cells which can withstand high radiation environments such as those in the Van Allen radiation belts around Earth and in the radiation belts around Jupiter.

Critical technology experiments will be initiated on two advanced solar dynamic receiver concepts (one based on the Stirling cycle, the other based on the closed Brayton cycle), and the demonstration of lightweight, highly accurate solar concentrator technology will continue. Planned advancements in this area will result in a factor of three improvement in the specific power of solar dynamic power systems. Analyses of thermal energy storage systems will be completed and work started on thermal energy storage materials for testing on an eventual flight experiment. Materials with high thermal conductivity and high heat of fusion are needed to develop efficient and lightweight thermal energy storage systems and receivers.

Work will continue on extending the performance of lithium-titanium-disulfide batteries to reach a 1000-cycle lifetime which would make such a battery suitable for future planetary missions and on conducting advanced nickel-hydrogen battery cell tests leading toward the goal of 100 watt hours per kilogram, which is about five times greater than the current state of the art.

Experimental and analytical efforts to study droplet formation, heat transfer mechanism and zero-gravity phase change, and fluid flow phenomena will be conducted to evaluate materials and designs and develop the required technology base for advanced radiator concepts that will allow the large amounts of heat generated by high power systems to be dissipated. High-frequency power system designs and components will be developed to reduce the weight, increase the life, and meet the space radiation and temperature constraints. Experimental power systems, biased to simulate space charging effects, will be tested in vacuum chambers to determine the possible detrimental effects of high-voltage arcing and to develop designs which will be suitable for use in civil missions.

Research will continue on developing efficient air, water, and waste processing technologies, sensor and monitoring instrumentation and controls technology for air and water quality, as well as the development and validation of computerized simulation techniques to support and guide the research effort.

Propulsion research and technology

The objectives of the propulsion research and technology program are to develop and validate accurate analytical simulations of the chemical and physical processes that occur in space propulsion systems and to evaluate the potential benefits and feasibility of advanced concepts that will improve our propulsion capabilities well beyond those that are achievable with today's operational systems. Included are propulsion systems for advanced transportation systems and for planetary ascent vehicles. Also included is Earth-orbiting satellite auxiliary propulsion needed for such functions as attitude control and station keeping. Finally, a part of the program is dedicated to the identification and evaluation of very high-energy advanced propulsion concepts that, if proven feasible and ultimately practical, would provide a quantum leap in propulsion capabilities that could be applied to a number of the above applications.

Advanced transportation propulsion technology is directed toward the continued expansion of fundamental knowledge and understanding of rocket engine processes and principles and toward advanced concepts leading to more efficient and effective component and engine systems that will provide enhanced payload delivery capability for future space transportation vehicles. Fundamental efforts are focused on the development and experimental verification of combustion instability codes, unified computational fluid dynamics codes, impeller flow models, soft seal rub dynamic models, and fluid dynamic processes in combustion chambers and nozzle boundary layers. Considerable progress has been made in development of analytical representation of these phenomena. Experimental verification of these analytical models and techniques remains to be accomplished. Advanced concept efforts concentrate on promising design concepts and high energy density propellant combinations to provide enhanced propulsion system performance.

Emphasis is on metallized gelled propellants, compliant thrust chamber fabrication techniques, and high-temperature (4000 degrees Fahrenheit) combustor materials. Hydrocarbon fuels have been successfully gelled and metallized (with aluminum) and flow characteristics established.

Lunar/planetary propulsion technology is directed toward the exploration and evaluation of propulsion concepts utilizing planetary *in-situ* propellants to reduce Earth launch vehicle requirements for potential future space exploration missions. Studies indicate oxygen and aluminum could be extracted from lunar soil and that oxygen and carbon monoxide could be obtained from the carbon dioxide in the Martian atmosphere.

Primary emphasis is on lunar-derived propellants, with the most attractive concept being a gelled aluminum/oxygen monopropellant. Efforts are focused on safety and handling characteristics and on propellant rheology.

Auxiliary or low-thrust propulsion technology is directed toward improved capabilities in resistojets, arcjets, ion thrusters, magnetoplasmadynamic (MPD) thrusters, and long-life, efficient gaseous and storable liquid chemical propellant rockets. The program has already achieved a number of notable successes including: (1)

achievement of an extraordinary increase in chamber wall temperature with conventional chemical propellants leading to a 20-second increase in the specific impulse for standard chemical engines; (2) completion of 1000-hour, 500-cycle autonomous life test of an arcjet with a high specific impulse of 450 seconds; and (3) completion of a 500-hour, 10-kilowatt ion engine life test.

Advanced propulsion concepts studies continue to investigate promising capabilities not yet within our reach. Efforts include determining the critical research needs for antimatter propulsion and the selection of critical experiments, evaluating the status of fusion propulsion and selecting possible applications to NASA missions, and appraising the ram cannon. A magnetically confined microwave-induced plasma experiment has been initiated at the Massachusetts Institute of Technology as the first experimental effort under the advanced concepts program.

In the advanced transportation propulsion program, efforts in 1990 will be aimed at developing an experimental data base for validating combustion instability analyses. Efforts also will be initiated to quantify the ignition and combustion characteristics of metallized hydrocarbons gel fuels, and activities will be directed toward promising cryogenic metallized propellants to study propellant rheology and ignition and combustion physics. Testing of very high-temperature materials (4000 degrees Fahrenheit) as potential combustor liners also will be conducted.

In the lunar/planetary propulsion program, efforts in 1990 will be directed toward establishing the safety and handling characteristics of oxygen/aluminum monopropellants. Laboratory experiments will be conducted to understand the physics of gelling liquid oxygen and aluminum mixtures. Combustion devices will be fabricated and tested to investigate the ignition and combustion characteristics of lunar/planetary derived propellants.

A combustion shear layer model of low-thrust chemical rocket combustion will be developed as part of the overall effort to understand the fundamental physics of rocket combustion. A 50-kilowatt arcjet facility will be completed and made operational with plans to complete the initial life tests of a 5-kilowatt arcjet in FY 1991. As part of the continuing effort to improve the performance of ion engines for future space exploration of a 100-hour life test of a 50-kilowatt ion engine will be completed. This will mark a significant milestone on the way to advanced electric propulsion. Work will continue on moving to higher power levels (over 200 kilowatts) on MPD thrusters to determine the degree of efficiency enhancement.

Advanced propulsion concept studies will continue toward the objective of identifying the most fruitful areas for agency emphasis and the critical experiments necessary to prove their potential. The magnetically confined, microwave-induced plasma experiment at the Massachusetts Institute of Technology will be in full text operation.

Materials and structures research and technology

The objective of the materials and structures program is to provide technology that will enable the development of future spacecraft, large-area space structures, and advanced space transportation systems with significant improvements in performance, effi-

ciency, durability, and economy. Major technical areas of emphasis focus on fundamental understanding of the processing; properties and behavior of advanced space materials, including long-duration synergistic space environmental effects on materials; development of lightweight space-durable materials; computational methods in chemistry to enable the prediction of physical properties and environmental interactions involving under space and reentry conditions; nondestructive measurement science for advanced materials; tribological aspects of materials behavior in the space environment; and the development of a wide variety of metallic, intermetallic, ceramic and carbon-carbon materials for thermal protection systems. Structures technology focuses on the development of erectable and deployment structural concepts; methods for in-space construction, monitoring, and repair of large complex structures; dynamics of flexible structures and concepts for active configuration control and vibration suppression; new structural concepts for active cooling of hot structures and cryogenic tanks for advanced Earth-to-orbit rocket propulsion systems, hypersonic vehicles, and orbital transfer vehicles; and efficient analysis and design methodology for advanced space structures, including multidisciplinary analysis and optimization.

In the materials science program, efforts are underway to theroretically develop and experimentally verify methodologies for predicting the properties of polymers, to develop new high-toughness high-temperature polymers, to develop new nondestructive measurement capabilities using acoustic microscopy and fiber optic systems, and to conduct fundamental studies of solid lubricants in the space environment. In the space durable materials program, contamination studies are focusing on the development and verification of analytical codes for correlating in-flight data and ground-based experiments. Atomic oxygen studies include developing new ground-based atomic oxygen simulation facilities, conducting a program to compare and calibrate a wide range of ground-based facilities for simulating atomic oxygen exposure in low Earth orbit, and measuring long-term oxygen exposure effects on various materials. In the area of micrometeoroid/debris impact, ground-based experimental studies of hypervelocity impact on metallic and nonmetallic materials are continuing and, in the area of radiation exposure, a new facility is being developed to provide a combined thermal-electron-radiation capability. In the aerothermal materials program, processing, fabrication and testing of various ceramic materials for thermal protection systems are being carried out. In the generic hypersonic program, work is underway to develop, fabricate and evaluate very thin gage oxidation-resistant intermetallic and carbon-carbon materials for lightly loaded hot structures.

In FY 1990, the materials program will continue to place a strong emphasis on space environmental effects on materials and on developing materials with enhanced space durability. The space durable materials program will focus on developing new ground-based capabilities for accelerated material testing, on the development of analytical capabilities to predict long-term in-space materials performance from ground-based studies, and on flight experiment opportunities provided by collaborative efforts with the European Space Agency and the Department of Defense. Computational

chemistry studies will focus on developing and verifying capabilities to predict the properties and behavior of bulk polymers. Non-destructive measurement studies will focus on new capabilities to quantify microstructural parameters and fatigue damage characterization in metals. An area which will begin to receive greater emphasis is tribology in the space environment in coordination with a planned new structures initiative in space mechanisms.

The aerothermal materials and structures activity will continue development and testing of lightweight cryogenic tank concepts and advanced ceramic thermal protection systems (TPS) with higher temperature capability (approximately 3000 degrees Fahrenheit) and high structural strength. Design and analysis emphasis will be placed on validating design concepts for curved tank structures. Curvature causes more severe, realistic, thermal stresses than flat panels, which may not be suitable for complex shapes. Integral and separate cryogenic tank subscale components will be fabricated and tested to validate design concepts for advanced thermal protection systems and structural integrity. Ceramic composite TPS design concepts, including advanced fabrication methods using improved multiaxis weaving, will be continued in FY 1990.

The goal of improving transverse mechanical properties by at least 50 percent will be emphasized to enable effective use of ceramic composites as both structural components and TPS. Here, as well, cured TPS ceramic-ceramic concepts will be fabricated and validated using arcjet tests required to achieve the high heating rate environments for hot structures. These activities will be supported by a strong program in analytical and experimental methods to predict aerothermal loads. An increasing part of this activity will be extensive testing of hot structures, including cryogenic tankage concepts.

The effort in space-related hypersonics will emphasize generic concept for lightweight structures with complex shapes, including novel concepts for areas of extreme heating, such as leading edges and nose caps. One concept currently under study, in small scale, is a spinning leading edge. Advanced joining and shaping methods will be studied for thin-gauge sheet and multiwall concepts, again emphasizing curved complex surfaces. Work also will continue on carbon-carbon materials including methods to improve transverse properties. Various coating concepts will be explored to improve oxidation resistance of advanced carbon-carbon composites. Small-scale components will be fabricated and tested under simulated service environments up to 3000 degrees Fahrenheit to assess the potential for carbon-carbon high-temperature structures for hypersonic vehicles.

Space data and communications research and technology

The space data and communications research and technology program is directed toward developing technology to control, process, store, manipulate, and communicate space-derived mission data and enabling new communications concepts.

In the area of advanced data systems, neural network devices for high reliability space applications have been demonstrated. These neural memory devices have the potential to replicate the capability of the human mind for pattern recognition and deductive rea-

soning and will serve as hardware-based natural intelligence for space applications. A pilot application and evaluation of a software management environment was completed. An advanced software life-cycle simulation development was applied to a model of the space station software development environment. These tools are intended to provide software managers with critical tools for evaluation of software development cost and schedule. A reusable software component library in an Ada development laboratory was demonstrated.

Reliable, ultra-high-rate, communications links for future NASA missions are predicated upon the communications research and technology base. Prototype Ka-band monolithic microwave integrated circuits have been designed, fabricated and tested. These circuits are planned for use in phased-array antennas for future deep space missions, such as Cassini and the Mars Rover. An experiment was successfully conducted on a multiple element phased-array feed with electronic compensation for antenna distortion. A near perfect far-field antenna pattern was produced. Such a concept will find application in large radiometry antennas for Earth remote sensing at the 10 to 100 Gigahertz frequencies. Continuing tests on a gallium aluminum arsenide semiconductor laser operating at 30 degrees Centigrade and at a modulation rate of 100 Megahertz showed a minimum drop in power which is projected to provide a life of four years of continuous operation. Long lifetime space-qualifiable lasers are critical for practical space optical communications. For deep space communications applications, a semiconductor diode array was successfully employed in pumping a yttrium-lithium-fluoride solid-state laser doped with holmium and erbium to emit at the eye-safe wavelength of two micrometers. Finally, a complete monolithic solid-state photodiode with ten amplification stages was fabricated and successfully tested at 25 degrees Centigrade with a gain of 200 times in signal strength and a bandwidth of greater than two Gigahertz. This device represents a significant technical achievement for reception of space optical communications signals.

An erasable neural network-based associative memory system for high reliability space applications will be demonstrated. A generic software life-cycle model will be validated by application to a number of NASA-managed software projects. The software management environment development will be completed, and expert system approaches for dynamic simulation of various software systems will be demonstrated toward meeting the objective of providing a complete and integrated set of tools and measures for management and acquisition of major software systems. Funding will be provided to continue support for the software engineering research center at the University of Houston at Clear Lake for continued research in Ada software development, integration, and validation for embedded and distributed systems.

In FY 1990, work continue on increasing the productivity yield of monolithic microwave integrated circuits, since many of these circuits are needed in a full-scale flight phased-array antenna microwave link. The electronic compensation of distorted antennas will be scaled to radiometric antenna sizes and frequencies needed for geostationary Earth observations. A monolithic phased-array of ten-

edge emitting semiconductor laser diodes will be successfully combined into a single far-field beam. Additional work will concentrate on various methods and techniques for modulating the beam at rates in excess of 100 Megahertz. Surface-emitting semiconductor diode arrays are a new promising technology with peak powers in the range of watts. Various methods for modulating surface-emitting diode arrays at rates in excess of 100 Megahertz will be investigated. In the deep space laser communications applications area, techniques for modulating the semiconductor pumped solid-state lasers will also continue. The solid-state semiconductor avalanche photodiode devices will be investigated to ascertain the gain versus parameters such as the number, composition, and size of the superlattice layers.

Information sciences research and technology

The objective of the information sciences research and technology program is to provide new concepts, techniques, system algorithms and architectures, hardware devices and components, and software in order to enable viable and productive space information systems.

In the computer sciences area, the distributed access view integrated data base (DAVID) system software has been built and tested to provide scientific users a transparent access to space data stored in dissimilar data bases. Demonstrations of DAVID for astrophysics applications have been given. The new center of excellence in space data and information sciences (CESDIS) was established at Goddard Space Flight Center in conjunction with the University of Maryland. A prototype intelligent data management front end using natural language, expert systems graphics, and a knowledge-based data management controller was integrated and demonstrated. In the concurrent processing research area, additional algorithms were successfully run on the massively parallel processor, including graphics/visualization, data base string search, and flow reactor simulation.

In the sensing area, the goal of high spatial imaging with simultaneous sharp energy resolution for x-ray and gamma-ray imaging spectrometers and cosmic-ray drift detectors has been advanced by the technique of employing a silicon drift detector to achieve better than 100-electron volt energy resolution over the soft X-ray spectrum to 10,000-electron volts in energy. These concepts have immediate application to the advanced X-ray astronomical facility and AstroMag missions. A semiconductor diode laser fabricated from gallium antimonide with indium and arsenic in various layers has successfully operated at the eye-safe region of 2.1 micrometers in wavelength at 77 degrees Kelvin. Such a demonstration means that laser systems at this wavelength have the potential of being injection locked for frequency stability.

In the photonics area, a real-time acoustic spectrum analyzer with frequency resolution of 50 Kiloherzt over a bandwidth of 24 Megahertz has been demonstrated. This analyzer has immediate potential for use in the Microwave Observing project. In addition, a liquid crystal television spatial light modulator for image subtraction, edge enhancement and associative memory applications has

been demonstrated for application to robotic image identification and recognition.

The area of high-temperature superconductivity has generic application across the spectrum of NASA uses. Research using a scanning tunneling microscope has ascertained that the surface of yttrium-barium-copper-oxide high-temperature superconducting material is not superconducting. This result will impact the fabrication of devices utilizing the surface properties of these materials.

In computer sciences, research will be conducted under four major themes: information management, concurrent processing, software engineering, and artificial intelligence. The block grant funded center for aeronautics and space information systems (CASIS) at Stanford University will conduct research in neural networks and cellular automation, man-machine systems, high-speed network and telecommunications and signal processing. The recently established center for excellence in space data and information sciences (CESDIS) at Goddard Space Flight Center will stimulate university and industrial research on NASA long-term space and earth sciences data and computational problems through the peer-reviewed research proposals.

Artificial intelligence techniques for information extraction and autonomous decision making, utilizing high-dimensional multispectral and multisensor image and nonimage data, will be developed and demonstrated.

A generic software engineering process simulation (SEPS) model assessing the effect of changes in technology, software engineering development environment, and management policy on various software development projects will be developed.

Fundamental research in automated technology for ingest, identification, categorization, and systems management and control of object-oriented data sets will be initiated; research in intelligent data base management processes, such as intelligent query formulation and search strategies based on expert knowledge, will continue, as well as research on concurrent processing algorithms for space research and data analysis.

Evaluation and validation of fundamental principles of concurrency for reliable and parallel computer architectures will be conducted, and applications and benefits of conceptually new memory technology in concurrent processing applications will be evaluated.

Several technologies will be developed for high-energy astrophysical research, including a detector with maximum energy range and simultaneous energy resolution. A demonstration of an X-ray cooled calorimeter spectrometer with 10-keV sensitivity for x-rays from 0.1 to 10 keV, and a room temperature X-ray and gamma-ray spectrometer employing detectors and arrays made from mercuric iodide appears promising. The 2.1-micrometer wavelength region is technologically interesting because detectors exist that can enable better measurements of coherent backscattered radiation. Since this region is also of scientific interest to earth observations, research will continue on a laser system configuration for remote-sensing in this eye-safe wavelength region.

In the area of photonics, the key spectrum analyzer performance parameters such as resolution, dynamic range, and tonal cross-talk will be evaluated. Spatial light modulators are the key component

in the utilization of the concepts of optical signal processing for applications such as robotic vision and image identification. Real-time holographic writing techniques adaptable to a variety of spatial light modulators will be researched.

In the area of high-temperature superconductivity, thin films are exceedingly important since they are employed in a vast number of detector applications, such as the sensing of electromagnetic radiation, magnetic fields, and use in superconducting cavities for ultra-stable frequency applications in space clocks. Research will continue on the various high-temperature superconducting materials for thin film devices for space application.

Controls and guidance research and technology

The objectives of the controls and guidance research and technology program are to develop and validate advanced controls algorithms for future complex spacecraft, e.g., large flexible antennas, segmented precision optical telescopes and interferometers, multi-instrument Earth observing platforms and space stations; to develop computational control tools for spacecraft control system design, analysis, and simulation, where modeling several hundred to thousands of states is required for an accurate description; to produce the technology for advanced sensors and actuators; to provide the basis for onboard guidance, navigation, and control techniques for future space transportation systems; and to define and develop methodologies for the design and validation of highly reliable advanced flight-crucial controllers.

During the past year algorithms, sensors and actuators were successfully tested in the large flexible vertical beam/antenna test facility at Marshall Space Flight Center for initial entry into our data base. Computational controls capability was further advanced with connecting topology systems (CONTOPS) maturity and the generation of a broad computational controls plan to help overcome the problems of solving large order systems. The fiber-optic gyro continues to show the initial promise of significantly reducing the cost, complexity and power demand through the successful demonstration of an eight-component optical chip.

In space transportation technology, progress was made in advancing our understanding of adaptive control for aerodynamically assisted orbit transfer aerobraking and aerocapture vehicles, precision guidance and navigation through planetary atmospheres from space to a safe touchdown area, and in designing and analyzing highly reliable fault- and damage-tolerant flight-crucial control systems.

Spacecraft controls algorithm testing and comparisons will begin using a new ground-based capability that provides for full-scale flight hardware testing. Research and testing will continue into the application of distributed optical sensors and magnetic actuators for lightweight flexible space structures in order to reduce the weight and number of these elements required for holding precise pointing and system shape.

Theoretical controls work in the field of precision structures will be expanded. The new thrust in computational controls will be matured to upgrade and expand the analytical tools and capability to analyze future large space systems. The successfully tested eight-

component optical chip version fiber-optic gyro will be extended to a closed-loop demonstration using a proto-flight chip.

Guidance and controls technology for space transportation vehicles will continue to emphasize the development of algorithms for onboard real-time application and the development of advanced information processing architectures that are highly reliable, and fault and damage tolerant. Ada advantages and overhead burden will be investigated for control system use and deficiencies identified and documented for future correction. Emphasis will be placed on reducing operational avionics subsystem software generation, validation and support costs for new generation vehicles, such as the advanced launch system.

Human factors research and technology

The objectives of the space human factors research and technology program are to provide a technology base for intelligent operator interfaces, especially with highly automated systems, and to develop a new generation of high-performance space suits, gloves, end effectors and tools to meet the needs of new space activities and missions. These objectives include: development of guidelines for man-machine interfaces in spacecraft and work stations and computer-generated models of human performance, capabilities and limitations in weightless or partial gravity environments. The areas of human factors research emphasized are crew-station design and extravehicular activity (EVA).

Crew-station research focuses on: (1) development of human-computer interface technology and graphical presentations, including effective multidimensional visual and aural displays and applications of artificial intelligence to such displays; (2) development of a technology base for autonomous vision and other perceptual systems, virtual work station technology, and computational vision systems for space operations and maintenance; and (3) development of data bases related to human strength and motion and body positions in zero or partial gravity environments. Test and evaluation are emphasized in all three areas.

Extravehicular activity (EVA) research builds on progress in the design, testing, and operational evaluation of EVA suits and subsystems, including gloves, end effectors, and tools needed in EVA.

Crew-station research accomplishments have included evaluation of human performance in zero gravity with direct control devices, testing of acknowledge acquisition method for use in interfacing with artificial intelligence-based systems, and completion of a design tool for building graphical displays. Mathematical and computational models of human vision were used to develop models of human perception of spatial location and motion. Based on these models, a neural network for autonomous motion sensing was developed and evaluated. Work on an initial operating configuration of a virtual work station was completed so that testing could begin. The data base on human strength, motion and human performance effectiveness in zero gravity was updated.

EVA human factors research focused on development and test of a new, high-pressure EVA glove and glove materials; completion of the fabrication of a highly dexterous, multidegree-of-freedom mechanical end effector and its test in zero gravity; and completion of

extensive tests of an electron end effector with built-in force feedback. Installation of a laser-based anthropometric mapping system at the Johnson Space Center was completed, and data collection began for range of motion and other body model variables. Electromyographic recordings of astronauts' strength and physical workload (heart rate) began.

Human factors research in FY 1990 for crew-station operations will include applications of laboratory test results on new display concepts to more realistic working environments on Space Station Freedom. Human information exchanges with "smart" embedded systems will be tested so that firm design guidelines may be issued. Virtual vision and three-dimensional aural work stations will be tested, and computational models of human visual and auditory systems will be validated in such tests. Coding of human vision, via mathematical models, will be verified by these and other tests. The role of the human as a teleoperator will be evaluated as a result of advances in robotic end-effector technology. It is expected that EVA glove fabrication and material forming techniques will be completed so that high-pressure EVA gloves can be produced for a wide variety of applications in a quicker, more effective manner. Mobility of the suited astronaut will be a major focus, so that appropriate methods to achieve human foot and shoe motion can be obtained for EVA activities.

Space flight research and technology

The purpose of the space flight research and technology program is to flight test enabling technologies which require the actual space environment for validation. Flight data obtained from in-space research and experimentation will be used to validate and verify analytical models, prediction techniques, and ground test methods and facilities. This program encompasses the identification and definition of in-space flight experiments; the design, fabrication, and flight certification of experiments in preparation for space validation; and the development of unique, special purpose experimental hardware systems to facilitate technology validation in the space environment.

The space flight experiments being conducted within this program include the long duration exposure facility (LDEF), cryogenic fluid management flight experiment (CFMFE), orbiter experiments (OEX), light detection and ranging in-space technology experiment (LITE), and the identification and definition of space flight experiments which will provide solutions to critical space technology problems.

The LDEF has been in space since 1984, subjecting 57 experiments and the structure to erosion effects of the space environment. Preparations are being made for the return of LDEF on STS-32 in November 1989. Several experiments are being combined on the CFMFE to better understand the processes of storage, acquisition, and transfer of cryogenic fluids in the near zero-gravity space environment. Feasibility studies which define the experiments and determine technical feasibility of the flight concept will be concluded. Preliminary development of specific hardware unique to the success of the experiments (such as flowmeters and fail-values) will begin. Four OEX research experiments which charac-

terize the space transportation system orbiter aerodynamic/aerothermodynamic environment will begin the second of a planned six-flight series. Research experiments to measure the aerodynamic heating effects of tile gap geometry and tile surface catalytic properties, to provide space flight data on durable high-performance material concepts and to evaluate aerodynamically induced decelerations in the free molecular flow flight regime are in final development and will be integrated into Columbia (orbiter vehicle 102). LITE will develop and validate the capability of light detection and ranging (LIDAR) systems as an in-space research tool for measuring aerosols and better understanding the Earth's atmospheric phenomena. Final design will be completed and hardware fabrication initiated for this experiment in FY 1989. A workshop will be conducted to review critical space technology issues facing the U.S. in the immediate future. These problems/needs will be used to guide research and technology development in the industry, university and government ground-based facilities and will provide the basis for identifying future space technology experiments.

The LDEF will be retrieved in early FY 1990, and the 57 experiments and the structure will be distributed to the researchers and technologists for analysis and reporting of the flight results. The conceptual design study for the CFMFE will be initiated, and prototypes of the liquid hydrogen and gaseous flow meters and the cryogenic relief valves will be completed. Ground testing of the prototype concepts will provide assurance that these concepts are viable for continued spacecraft development. Flight testing of the orbiter experiments will continue through FY 1990. Four additional flights will be completed, and analysis of the flight data will be an ongoing effort throughout the year. In FY 1990, fabrication of the remaining components for LITE will be completed and tested. Assembly of the components will be initiated in preparation for a launch readiness date of 1993. A group of space technology experiment definition studies will be initiated to provide solutions for critical technology problems/needs identified in the above-referenced workshop.

Systems analysis

The objectives of the systems analysis program are to identify technology requirements for prescribed mission concepts and opportunities for enabling new and improved concepts, to integrate these into a comprehensive set of technology planning options, and to generate candidate plans to develop these technologies in a timely manner. Close coordination with the Office of Space Flight, Space Science and Applications, Space Operations, Space Station, Exploration and other users is maintained to ensure proper understanding of missions and to enable better prioritization of high-leverage technologies. This analysis program is directed at the systems-focused areas of space transportation, spacecraft, and large space systems and at emerging, new, mission concepts and mission-enabling technologies.

Spacecraft systems analysis is concentrated in five science and applications areas: astrophysics, space physics, Earth science, communications, and solar system exploration. In FY 1989, efforts are

focused on the critical technologies associated with Earth science observations for understanding global change.

The space transportation systems analyses are focused on advanced Earth to orbit (ETO) vehicles, aeroassist space transfer vehicles (ASTV), and advanced space transportation systems conceptual design and analysis methods. The ETO studies include the technology to support an advanced heavy-lift launch vehicle, a second-generation reusable manned vehicle, and future low-cost space transportation systems. The ETO studies also include the definition of nonintrusive instrumentation and measurements applicable to the ascent and entry speed range of an ETO vehicle.

Three specific study areas constitute the large space systems analysis program: (1) systems analysis methods, to develop and maintain advanced analytic simulation/emulation computer-based capabilities for determining the operational characteristics of large space systems, predicting nominal and worst-case failure modes, and identifying critical system/subsystem interfaces; (2) future space systems, to address mission and system requirements and to identify their associated technology needs and trends; and (3) in-space research and technology experiments planning, using the shuttle, space station, and other space assets are laboratory facilities.

In FY 1990, many of the long-range efforts currently underway will be continued. These efforts will have substantial impact on the development of future CSTI and Pathfinder technology program elements, as well as on identifying thrusts for the research and technology base and the flight experiments programs. For spacecraft systems, the major focus will be to examine the technology planning options for more extensive future exploration of planet Earth. Within the astrophysics area, activities will center on the technology requirements for interferometric observatories across a range of wavelengths. Work will continue to synthesize the analytical techniques developed for past studies into a general purpose spacecraft systems analysis capability. Cooperative studies in solar system exploration and space physics will identify technology requirements for key potential future missions.

The transportation systems analysis effort will continue the definition of key areas for lower cost transportation technologies and for technology growth in space transfer vehicles and advanced delivery systems to low Earth orbit. The analyses will focus on concepts and technology requirements for a possible lunar space transfer vehicle, a heavy-lift launch vehicle, and a shuttle-derived vehicle.

In large space systems, the transition of the systems analysis focus from the initial space station to an expanded mission perspective, including evolutionary space stations, lunar base, and long-duration manned space trips, will be continue. The primary thrust of the extended perspective is to ensure that the research and technology base program is structured to enable and support the needs of these missions in the turn-of-the-century time frame. Additionally, the FY 1990 program will continue to include planning for the use of the space station as a facility to support research and technology.

In FY 1990, efforts will continue to address studies and analyses of opportunity-oriented technologies and their impact on enabling new mission/system capabilities. These studies will explore the potential applications of emerging, high-leverage technologies such as superconductivity, antimatter, and high-level machine learning to the formulation of new or improved system concepts.

University space research

The objective of the university space research program is to enhance and broaden the capabilities of the nation's engineering community to participate more effectively in the U.S. civil space program; it is an integral part of the strategy to rebuild the space research and technology base. The program responds to the need to remedy the decline in the availability of qualified space engineers by making a long-term commitment to universities aspiring to play a strong engineering role in the civil space program. The program utilizes technical advisors at NASA centers to foster collaborative arrangements, exchange of personnel, and the sharing of facilities between NASA and the universities. The program elements include *the university space engineering research program* that supports interdisciplinary research centers; *the university investigators research program*, providing grants to individuals with outstanding credentials; and *the university advanced space design program*, which funds advanced systems study courses at the senior and graduate levels.

The university space engineering research program is designed to advance the traditional engineering disciplines applicable to space and bring together the knowledge, methodologies, and engineering tools needed to advance future space systems. The research centers promote the kind of multidisciplinary teamwork that systems technological problems demand and bring individuals from a wide range of engineering and scientific fields into a single research structure. These partnerships provide the universities with a broader charter for independent research and enable new mission concepts and ideas that might alter NASA's own visions on the civil space program. In April 1988, the Office of Aeronautics and Space Technology selected nine universities from a total of 115 proposers.

The objective of *the university investigators research program* is to sponsor individual research on highly innovative space technology concepts directed toward far-term mission use. The grants will be awarded to persons who have a demonstrated record of performance in generating and validating innovative concepts. Selection of grantees will be made through a competitive evaluation conducted by a peer review selection panel.

The objectives of *the university advanced design program* are to foster engineering design education in the universities and to supplement NASA's in-house efforts in advanced planning for space systems design. The study topics include potential missions which would be undertaken during a 20-30 year period, beginning with the space station initial operating configuration scheduled for the mid-1990's. The university advanced design program has been an effective mechanism for integrating the educational objectives of

the university community with the advanced engineering design interest of NASA.

The FY 1990 program funding will continue the support to the nine incumbent centers of the university space engineering research program. Eminent researchers, selected in FY 1989, to participate in the university space investigators research program will continue to be funded and additional three-year grantees will be added. The total number of grants will reach a level of approximately 20 during FY 1990. The university advances space design program will be expanded to approximately 34 universities.

CIVIL SPACE TECHNOLOGY INITIATIVE (CSTI) PROGRAM

	1989 current estimate	1990 budget request
Automation and robotics.....	\$25,900,000	\$25,900,000
Propulsion.....	36,100,000	37,400,000
Vehicle.....	13,300,000	36,000,000
Information technology.....	15,900,000	15,600,000
Large structures and control.....	19,500,000	18,900,000
High-capacity power	11,100,000	10,700,000
Total	121,800,000	144,500,000

The CSTI, begun in FY 1988, was the first step in revitalizing national civil space capabilities for future Earth orbit missions. The CSTI will develop technologies to enable efficient, reliable access to Earth orbit, enhance operations in Earth orbit, and increase the effectiveness of science missions from low Earth orbit.

The objective of the automation and robotics program is to exploit the potential of artificial intelligence and telerobotics to increase the capability, flexibility, and safety of space and ground operations while decreasing associated costs. The automation and robotics elements consist of a sequence of evolutionary demonstrations using testbeds, mockups and shuttle and spacecraft operations in five core technology elements: sensing and perception, control execution, task planning and reasoning, operator interface, and systems architecture and integration. In FY 1989, the telerobot demonstration facility at the Jet Propulsion Laboratory will perform its first test in which the concept of traded control between a human operator and automatic control system within a task will be demonstrated. Also in FY 1989 first use of an expert system for monitoring the Space Shuttle's communications during flight was demonstrated. In addition, an autonomous system for thermal control will be demonstrated on a thermal control system testbed.

The objective of the propulsion program is to provide a validated design and analysis capability that can be applied to design and development of advanced propulsion systems for future low-cost reusable Earth-to-orbit vehicles and expendable or recoverable boosters. The program will validate methods and techniques developed from experiments with small laboratory scale models by designing, fabricating and testing full-scale models. The technology hardware will be highly instrumented and will be capable of varying operating conditions over a wide range, in order to provide a broad experi-

mental data base with which to validate analytical codes and new design techniques. The booster technology program will investigate both solid-liquid hybrid boosters and pressure-fed bipropellant liquid boosters as alternate propulsion concepts for the space shuttle. Performance models will be generated and verified with data from static firings of test articles with increasing size. Initial design and analytical test validation at a component level has started.

In the vehicle area, the aeroassist flight experiment (AFE) will investigate critical design and environmental technologies applicable to the design of an aeroassisted space transfer vehicle (STV). Application of this technology has the potential for increasing the payload of an STV by a factor of two for transfer missions from the moon and geosynchronous orbit to low Earth orbit. Computational models and design tools have been developed to support the design on an STV, but ground facilities are inadequate to validate them. Flight experiments are necessary to provide this validation in the actual conditions associated with aerobraking. Specifically, the AFE will provide critical aerothermodynamic parameters including radiative heating levels, wake flow base heating levels, aerodynamics and control characteristics, and wall catalysis effects. Alternate thermal protection system materials which permit lightweight, flexible drag devices will be evaluated. A program requirements review has been completed and experiments selected.

The objective of the information technology program is to develop technologies that will enable active and passive detection and imaging of electromagnetic radiation and the development of advanced techniques, processes, and systems for high-speed/high-volume data storage and processing. These activities will involve discovery, invention and development of new techniques, materials, devices, components, and hardware systems. The sensor activities are concentrating on systems for the relatively unexplored submillimeter portion of the electromagnetic spectrum. The data activities are concentrating on technologies for a new generation of high-speed general flight processors and high-volume data handling and storage systems. New sensors operating at submillimeter wavelengths have been invented. Through participation in a multi-agency consortium, technology feasibility studies and demonstration of critical components for a read/write optical disk were completed.

The objective of the large structures and control element is to develop integrated structures and control technology to enable the development of large, flexible and high-precision structures to meet long-range requirements for complex multibody platforms, spacecraft, and large scientific instruments. Current design and testing methodologies will be inadequate to assure on-orbit performance for integrated structure and control systems at the scale and precision being considered. Part of the program is developing technologies for advanced orbiting scientific instruments which use large, extremely precise reflectors which must be lightweight and assembled and aligned on orbit. Systems studies have started, and early lightweight panels have been produced.

In the power area, the high-capacity power program objective is to develop the conversion system the technology for a nuclear

power system capable of supplying high-capacity power over a long period of time. The emphasis is on thermal-to-electric energy conversion, high-capacity heat rejection, and high-capacity power management and distribution subsystems. Technology demonstration tests have been completed for a free-piston Stirling engine. Advanced radiator concepts have been identified with one-half the mass of previous systems.

The automation and Robotics estimates are based on a planned sequence of evolutionary ground demonstrations scheduled to run through 1996. In FY 1990, expert system demonstrations include coordinated control of multiple subsystems, using the thermal control system testbed, and control of the shuttle environmental control systems during launch processing. Robotics demonstrations will include the addition of an automated planner and the introduction of short time delays to simulate remote location operations.

The Earth-to-orbit propulsion program will continue in FY 1990 to conduct technology tasks to verify high-pressure ignition, combustion performance and stability, and heat transfer and cooling. Design and fabrication of large-scale turbopumps and design of combustors will begin. Analytical modeling, code development and advanced design methodologies will continue to be developed. The space shuttle main engine technology testbed program will continue with emphasis on testing to help map the internal dynamic environments of that engine for use in verification of simulation codes. The booster technology activities will define technology programs in the areas of solid fuel burning characteristics oxidizer injection concepts, and thrust termination. Combustor and tank pressurization technologies will continue to be studied in the pressurized liquid booster program.

For the AFE program in FY 1990, final designs of the carrier, aerobrake and instruments will be completed. Preparations for critical design reviews prior to starting fabrication of hardware will be completed. Preliminary design reviews will be held for software systems, and critical design reviews will be held for ground support equipment.

The information technology activities in FY 1990 will be based on development of detectors in the 4- to 10-micron region using molecular beam epitaxy doping techniques, in the 30- to 300-micron region using blocked impurity band phenomena. In the submillimeter wave region on quantum well local oscillator and superconducting tunnel junction mixers, backward wave oscillators and refrigerator technologies will also be investigated. The high rate/capacity data activities will continue on using four-processor, very high-speed, integrated circuit multiprocessors and will start development of a brassboard space flight optical disk recorder module. Preliminary design of on-board digital processors and correlators will be started.

In FY 1990, the large structures and control program will develop models and evaluate concepts for integrated structures and control systems. Future systems are expected to be large and flexible and possibly require extreme precision in configuration and control. Concepts of integrated pressure and active control will be investigated. Precision, segmented, lightweight reflectors will be fabricated; active vibration damping concepts will be developed; and precision panel control will be demonstrated on a single panel. A

large truss concept will be fabricated to demonstrate structural precision feasibility.

High-capacity power activities in FY 1990 will contain a major contracted effort to develop technologies for the 1050°K Stirling space engine. Testing of components will be completed and design efforts to include these components in the engine will be started. Critical technology development and advanced radiator concepts will be pursued for both the engine and thermoelectric space power systems. Technology developments on radiation-hardened, high-temperature power management systems will be performed.

PATHFINDER

	1989 current estimate	1990 budget request
Surface exploration.....	\$8,500,000	\$9,300,000
In-space operations.....	15,000,000	15,600,000
Humans in space.....	6,000,000	6,300,000
Space transfer.....	5,500,000	6,100,000
Mission studies.....	5,000,000	10,000,000
Total.....	40,000,000	47,300,000

Pathfinder, begun in FY 1989, is a program through which NASA is developing a broad set of technologies that will enable decisions on potential future space missions. Pathfinder is a critical focused technology program that will strengthen the technological foundation of the civil space program and the nation's leadership to go forward with ambitious future solar system exploration missions. This program is organized into four technology areas: surface exploration, in-space operations, humans in space, and space transfer. In addition, mission studies will be conducted to support the detailed formulation of mission requirements and technology options.

The technologies included in the surface exploration program are related to the gathering of scientific knowledge and technical understanding at mission sites on the moon and Mars. The in-space operations program area will address critical technologies for in-space assembly and construction and the repair of massive and complex systems in Earth orbit and at lunar and Martian orbits, and for advanced planetary operations, such as *in-situ* resource utilization. The humans-in-space program area will address the technology for improving astronaut productivity, maintenance, and health, and minimal or no dependence on resupply of expendables. The space transfer program will support transportation to and from Earth orbit, the moon, Mars, and other planets. The mission studies program will formulate options and alternatives for potential future space initiatives in human exploration of the solar system.

In the area of surface exploration technology, research will continue in planetary rover technologies, including surface mobility (both wheeled and legged), systems autonomy (including both ground control process automation and on-board software systems), on-board computation and guidance, including semiautonomous navigation and university research in mobile robotic research; in sample acquisition, analysis, and preservation, including compact

multispectral sensors for *in-situ* sample analysis; in autonomous lander technologies, including both active and passive sensor systems guidance, navigation and controls, including both precision landing and hazard avoidance during terminal descent, and low-mass, hazard-tolerant landing mechanisms; and in surface power systems, including advanced amorphous silicon photovoltaics cells and solar arrays and high-performance regenerative fuel cells.

In the area of in-space operations technology, research will continue in autonomous rendezvous and docking, including range and range rate active sensors with extended dynamic ranges and on-board guidance, navigation, and control to enable autonomous operations without ground-based human control; in-space assembly and construction, including structure component bonding and welding, and techniques for handling large, massive system elements; cryogenic fluid depot technologies, including microgravity cryogenic fluid analytic modeling, instrumentation to measure cryogenic fluid parameters in zero gravity, and the development of a ground-based testbed for model validation; and space nuclear power, focused on refractory metal reactors, solid-state thermoelectric power conversion, and thermal management technologies such as heat pipes.

In the area of humans-in-space technology, research will continue in extravehicular activity suits, including highly-dexterous, high-pressure gloves, suit end effectors and tools, and portable life support systems, including thermal management systems, and carbon dioxide removal; space human factors, including human-automation-robotic systems, artificial environment human-machine interfaces, and development of basic human performance models for exploration missions; human performance, including defining requirements for human physiological considerations pertaining to space radiation, including both solar and cosmic radiation and microgravity effects, such as artificial gravity systems; and advanced life support systems, including bioregenerative life support, such as food production chambers.

In the area of space transfer technology, research will continue in cryogenic (hydrogen-oxygen) engines for space transfer vehicles and for ascent/descent propulsion. This includes a breadboard and technology for high throttleability, long life with multiple firings, integrated engine diagnostics and controls, and designs for engine space-basing and -servicing. In research on a high-energy aerobraking for interplanetary mission applications, studies include computational fluid dynamic aerothermodynamic modeling for both the Earth and Mars atmospheric chemistries; thermal protection systems such as high-temperature ablative materials; guidance, navigation, and control, including both on-board optical unanticipated variations in planetary atmospheric densities. In addition, high-energy aerobrake configurations will be defined for both the Earth and Mars and for robotic and piloted missions applications.

In the area of mission studies, case studies will be conducted of possible future missions of human exploration, including both evolutionary scenarios involving the utilization of *in-situ* resources at both the moon and Mars and expeditionary missions to Mars. These studies will encompass both mission design options, the effects of alternative scenarios on NASA infrastructure and systems,

precursor mission requirements, and the technology needs of the exploration concepts.

IN-SPACE EXPERIMENTS TECHNOLOGY PROGRAM

In-space experiments technology program:

1990 budget request \$16,200,000

The purpose of the in-space technology experiments program (IN-STEP) is to provide validated, advanced space technologies to the designers for improving the effectiveness and efficiency of current space system and to provide major advancements for future space systems. For the past few years, highly innovative technology concepts have been identified in the research and technology base program that require testing or validation in the actual space environment in order to reduce the risk to the potential users and to increase the rate of transfer of advanced technologies into future space missions. Examples of these technologies include: behavior of fluids in the microgravity environment which is essential for the design of advanced thermal management systems, power systems, propulsion systems, and environmental control and life control systems; use of robotics in space construction, servicing, and other in-space operations; and environmental effects on materials from long-term exposure to the space environment.

This is a focused technology program that will coalesce many unique space technology concepts into defined flight experiments and will sponsor the hardware development of these experiments, so that these innovative technologies can be validated in the space environment for use in future space system designs. This program will concentrate on experiments performed primarily on the Shuttle mid-deck or in "get-away special" cans. Many will serve as precursors to experiments that will take advantage of the Space Station Freedom facilities available later in the decade. The three major elements of this program are the NASA in-space experiments, industry/university experiments, and the international experiments.

For example, included in these advanced technology experiments are several concepts generated at the NASA research and development centers such as the arcjet experiment, the space station structural characterization experiment (SSSCE), the debris collision sensor (DCS) experiment, and several innovative concepts currently in the definition phase. The arcjet experiment is an advanced reaction controller which will provide communications satellites with the capability of remaining on orbit for longer period of time, saving launch weight and improving efficiency. The SSSCE will provide space structure instrumentation on the space station, which will allow it to be used as a research facility, and will validate and upgrade current analytical modeling and prediction techniques for large space structures. The DCS experiment will validate a sensor concept which measures and identifies small debris in low Earth orbit that could be detrimental to spacecraft, space structures, and the safety of man. This debris is currently undetectable by ground radars and telescopes or current space sensors. These three experiments are in the conceptual design phase in preparation for space flight experiments.

The industry and university technology experiments program has identified over 200 innovative space technology concepts generated through U.S. industry and university research. Thirty-six of the most critical technologies were selected for the definition of in-space flight experiments. Five experiments were developed adequately to initiate conceptual design studies in preparation for design, fabrication, and ground certification. Typical examples of these five experiments are the tank pressure control (TPC) and the investigation of spacecraft glow experiments. The TPC experiment will validate predicted mixing and thermal stratification characteristics of fluids in a zero-gravity environment influenced by jet-induced flow. Data collected during flight may significantly reduce cost and complexity of fluid tanks in future spacecraft. The glow experiment will study the causes and effects of ram-induced radiation observed about certain materials when subjected to the space environment. A better understanding of the glow phenomena may reduce erosion of space structures and may provide an effective means of identifying/characterizing future spacecraft.

The international technology experiments program combines unique U.S. technology concepts with particular foreign hardware to capitalize on special flight opportunities. Typical of these experiments is the telerobotic intelligent interface flight experiment (TRIIFEX), which utilizes the German manipulator hardware developed and manifested on the Spacelab D-2 mission (STS-52, December 1991) to validate an advance force-feedback controller. The data received from this experiment will provide validation of telerobotic concepts which may be used to construct future space structures.

The FY 1990 funding will provide for the continued development of the selected space technology experiments for flight validation on the Space Shuttle and expendable launch vehicles in FY 1991 through FY 1993. Hardware design and fabrication will be initiated on the arcjet, DCS, TRIIFEX, and the five flight experiments under development in the industry and university program. Research instrumentation will begin to be developed for incorporation on Space Station Freedom in preparation for its utilization as a space research facility. Conceptual design studies for key flight experiments, which will provide solutions to critical technology problems and which are currently being defined in the industry/university program, will be initiated in preparation for in-space technology experiments on launch vehicles during FY 1994 through FY 1996.

SAFETY, RELIABILITY, MAINTAINABILITY, AND QUALITY ASSURANCE

FY 1990 BUDGET REQUEST \$23,300,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

Safety, Reliability, Maintainability and Quality Assurance:

1989 current estimate.....	\$22,400,000
1990 budget request	23,300,000

The Safety, Reliability, Maintainability and Quality Assurance (SRM&QA) program supports NASA's overall goals through activities in safety, reliability, quality assurance, maintainability, sys-

tems engineering, and program practices including independent assessment activities which reduce program risk. Specific objectives of the program are to:

- Identify and provide independent assessment of issues that have potential impact on mission success.
- Support in-depth reviews, studies, and analyses of issues and problems for readiness to launch.
- Conduct major tests and provide a viable problem reporting, corrective action, and trend analysis program throughout NASA.
- Perform radiation characterization on integrated circuits and complement the Air Force program for testing on-orbit radiation effects.
- Upgrade existing software standards, guidebooks, and training; and identify software management product assurance and automated work stations.
- Develop product assurance methodology for procuring reliable, custom large scale integrated (LSI) and very large scale integrated (VLSI) circuit components.
- Upgrade technology and emphasis the safety, reliability and performance of NASA's aerospace battery power systems.
- Plan, document, and establish policy for a NASA-wide SRM&QA Information System.
- Increase the safety of high hazard operations and develop safety risk management policy and guidance for all NASA programs.
- Support industrial, aviation, fire protection, and ground operations safety activities.
- Provide policies, procedures, and surveillance for all agency safety, quality, maintainability, and reliability activities.
- Develop and promulgate risk management and human factors safety programs that augment existing System Safety initiatives.

In concert with the NASA Centers and industry, efforts continue in the area of materials treatments and processes; integrated circuit product assurance; microcircuit radiation effects evaluation, aerospace and system safety related matters; and other areas in support of NASA-wide programs. The Non-Destructive Evaluation (NDE) Program places special emphasis on developing NDE techniques for assessing the quality of Solid Rocket Motors (SRM's). Development of qualitative and quantitative inspection and quality control techniques for microcircuits and semiconductors is being promoted. The Software Management and Assurance Program will continue to develop standards, specialized training, distributed software, corporate memory data bases, and guidebooks to facilitate improved software business practices. The Maintainability Program is now well established and continues to work with NASA programs on appropriate issues.

Previously, in response to the findings and recommendations contained in the Report of the Presidential Commission on the Space Shuttle *Challenger* Accident (Rogers' Commission), a system was developed to address the reporting and documentation of significant problems, assessment of problem resolutions, and analysis of

trends. Appropriate goals have been established and continue to measure the effectiveness of this new system.

The NASA Safety Program is focused on developing specific programmatic system safety management procedures and providing independent system safety review at Headquarters. The program will conduct assessments of and develop requirements for hazardous systems such as: radio frequency interference; ionizing radiation; toxic chemicals and propellants; and propulsion, ordnance and electrical systems. The assessment of Space Transportation System (STS) System Safety Management procedures and the development of specific programmatic systems safety procedures will be completed in FY 1989. System safety management procedures for Level I independent safety reviews, hazard analyses procedures and prioritization methods, system safety methodology development for flight critical software, and safety risk acceptance criteria recommendations are underway.

In FY 1990, the SRM&QA program will continue to provide leadership to all operational, programmatic, and institutional activists of the Agency. The key ingredient of this leadership is the continued integration of top level SRM&QA policies, procedures, and standards into each NASA program area. In the past year, key reliability requirements have been revised and expanded and deficiencies identified. Preferred techniques for implementing these new requirements will now be developed and additional research will be initiated to develop the technology to eliminate the deficiencies. These techniques will ensure that the most current and effective methods in reliability engineering will be applied to all NASA programs thus optimizing reliability, reducing risk, and enhancing mission effectiveness. The NDE measurement assurance program will continue to provide state-of-the-art, quantitative, advanced inspection techniques for solid rocket motors, composites, and ceramics. The program will also explore advanced inspection techniques such as microfocus x-ray, fiber optics, acoustic emission, computer tomography, and laser thermography.

The Systems Assessment program will continue to provide independent "second look" assessments of major NSTS flight hardware issues.

UNIVERSITY SPACE SCIENCE AND TECHNOLOGY ACADEMIC PROGRAMS

FY 1990 BUDGET REQUEST \$35,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
University affairs	(\$12,600,000)	\$15,900,000
Minority university research	(9,700,000)	14,100,000
Space grant college and fellowship		5,000,000
Total	(22,300,000)	35,000,000

UNIVERSITY AFFAIRS PROGRAM

FY 1990 BUDGET REQUEST \$15,900,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Graduate student researchers.....	(\$5,000,000)	\$6,800,000
Summer faculty fellowships.....	(2,500,000)	3,800,000
Innovative research	(2,400,000)	2,500,000
Space applications.....	(2,700,000)	2,800,000
Total	(12,600,000)	15,900,000

This program plus the Minority University Research program is proposed as a new budget line item this year in order to focus and enhance the resource and management devoted to university programs. FY 1990 funding will provide for continuation of agency-wide university and minority university programs which were previously budgeted in other NASA programs. As mandated in NASA's FY 1988 Authorization Act, funding is also provided for the National Space Grant College and Fellowship program.

The goal of the NASA University Affairs program is to create and maintain strong and mutually productive working relationships with the Nation's university community. In order to accomplish this goal the Office of External Relations and the Office of Space Science and Applications manage certain unique university programs that are agency-wide in scope and interest but are not within the direct responsibility of NASA program offices.

The specific objectives of the University Affairs program are:

To significantly increase the number of highly trained scientists and engineers in aeronautics, space science, space applications and space technology to meet the continuing needs of the national aerospace effort.

To facilitate the direct interaction, further the professional knowledge and stimulate the exchange of ideas between university faculty members and NASA scientists and engineers.

To support innovative research at U.S. institutions of higher learning, research which is in the formulative or embryonic stage and which would appear to have significant potential to advance space science and applications programs.

To provide for the development and use of a core, long-term U.S. national university capability to conduct multiyear, Earth discipline-oriented applied research and remote sensing.

Graduate student researchers

The Graduate Student Researchers Program, initiated in 1980, provides graduate fellowships nationwide to post-baccalaureate U.S. citizens to conduct thesis research at a NASA Center or to carry out a program of study or research at their home institutions. From 1980-1984, approximately 40 new awards were made each year. In 1985, NASA doubled the size of the program to make 80 new awards each year. Awards are made to graduate students for a maximum of three years. On an annual basis, the NASA sup-

ports approximately 250 graduate students pursuing the masters or doctorate degrees. The FY 1990 funding will allow for the continuation of the current program. The additional funding in FY 1990 will provide for the initiation of the Graduate Student Researchers program at the Kennedy Space Center and the John C. Stennis Space Center, as well as increasing the number of annual awards available yearly at each NASA center. In addition, student stipends will be increased as they have remained constant since 1985.

Summer faculty fellowship

The NASA Summer Faculty Fellowship program has completed 25 years of operation. This program has provided highly beneficial opportunities for engineering and science faculty throughout the United States by allowing participation in NASA research. This program has contributed significantly to the improvement of both undergraduate and graduate education, and directly benefited NASA, universities, faculty, students, and the Nation.

The Summer Faculty Fellowship program enables university faculty to spend 10 weeks working directly with scientists and engineers at NASA Field Centers on problems of mutual interest. Participants must have a minimum of two years teaching experience and must be citizens of the United States. The program is designed to further the professional knowledge of faculty members, to stimulate an exchange of ideas between participants and NASA, and to enrich the research and teaching activities of the participants' home institutions. This activity is operated cooperatively with the American Society for Engineering Education (ASEE).

Approximately 200-250 university faculty are supported annually for ten weeks. Evaluations conducted by ASEE of the program indicate that approximately 30-40 percent of the participating faculty subsequently receive NASA research grants or contracts.

The FY 1990 funding level is required to maintain the current program, allow initiation of the Summer Faculty Fellowship program at the John C. Stennis Space Center, increase the stipends which have remained constant for the past three years, and increase the available number of annual awards at each NASA center.

Innovative research

Over the past decade, it has become increasingly apparent that a key to the future health and well-being of the space science and applications program lies in having the capacity to explore new ideas or novel technical approaches to research. In response to this need, the Innovative Research program was established within the Office of Space Science and Applications to support research which, while still in its formulative stage, has already demonstrated potential for significant advances for space science and application programs. The program is intended to provide a mechanism for the funding of scientifically sound proposals which might not be funded through normal channels either because of their interdisciplinary nature or because they are, in some sense, speculative or risky. The long-term goal is to help the new ideas mature to a state of acceptability within particular science discipline resources.

The Innovative Research program was initiated in 1980, with announcements of the availability of funds and NASA's interest in receiving proposals for this type of research having been issued in 1980, 1982, 1985, and 1988. Emphasis in the program has been on the support of innovative research at universities and colleges. The primary criterion for inclusion in the program has been the originality and promise for innovation of the work being proposed. Over the past several years a number of major technical advances have resulted from research supported by this program such as the development of new infrared detector technology by the University of California-Berkeley using non standard scientific approaches.

As a result of the 1988 review cycle, 20 investigations at 20 institutions were selected with levels of support ranging between \$55,000 and \$250,000 per year. Awards were for one to three-year periods to allow adequate time for the development and demonstration of the validity of new ideas. The requested FY 1990 funding will provide for continuation of the current program and allow a few additional awards to be initiated.

Space applications

The objectives of the Space Applications program are to provide, through university grants, for the development and use of a core U.S. national university capability to conduct multiyear, discipline oriented basic and applied research in space applications; and to establish and maintain multidisciplinary remote sensing techniques and the use of those techniques in furthering the understanding of Earth sciences. This program has been the major impetus for the development of a geographically distributed network of universities which now comprise the prime source of the research and the development of techniques designed to use remote sensing data in the study of global Earth science processes and Earth resources management.

This program has achieved considerable success in developing a community of researchers knowledgeable in remote sensing science and in contributing toward the overall evolving maturity of spaceborne remote sensing. In FY 1990, the Space Applications program will focus on working with the university community to prepare for the space-based remote sensing of the Earth in the Space Station era.

MINORITY UNIVERSITY RESEARCH PROGRAM

FY 1990 BUDGET REQUEST \$1,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Historically black colleges and universities	\$7,700,000)	\$8,900,000
Other minority universities.....		2,000,000
Graduate student researchers program (underrepresented minority focus)	(2,000,000)	2,200,000

	1989 current estimate	1990 budget request
Undergraduate student researchers program (underrepresented minority focus).....		1,000,000
Total	(9,700,000)	14,100,000

The goals of the NASA Minority University Research program are to continue to implement aggressively the initiative for Historically Black Colleges and Universities (HBCUs); develop closer relationships with minority universities other than HBCU's; maintain the Graduate Student Researchers program (underrepresented minority focus); and introduce the Undergraduate Researchers program (underrepresented minority focus). The Office of Equal Opportunity Programs has the responsibility for the management of these programs.

NASA's HBCU initiative is mandated by Executive Order 12320 (issued September 1981) which requires Federal agencies to increase significantly the involvement of HBCUs in Federally sponsored programs. NASA has implemented this initiative primarily through research and training grants. In FY 1990, NASA is proposing the establishment of HBCU-Space Science and Engineering Centers of Excellence (SSECE) in order to be further responsive to the spirit of Executive Order 12320 and to help strengthen the research capabilities of selected HBCUs.

In FY 1985, Congress, through the Reports of the House Committee on Science and Technology, the House Authorization Committee, the House and Senate Appropriations Committees and the Senate Committee on Commerce, Science, and Transportation, instructed NASA to also build closer relationships with other universities that educate large numbers of minority students who are underrepresented in science and engineering, while not diminishing the agency's efforts towards the HBCUs. NASA made a commitment to Congress to: (1) establish or expand our research and development (R&D) relationship with a few selected universities; (2) encourage principal investigators to add underrepresented minorities to their research grants; and (3) increase participation of universities with substantial numbers of underrepresented minorities in our co-op programs, faculty summer assignments, graduate student researchers, post-doctoral fellowships and other programs.

NASA's proposed introduction of a Undergraduate Researchers Program (underrepresented minority focus) is based on the recommendations of NASA principal investigators. The concept also is consistent with the recommendations of the national Task Force on Women, Minorities, and the Handicapped in Science and Technology which urged the establishment of a variety of scholarships, fellowships, hands-on research opportunities, and other support to capture and develop these groups. It has become increasingly apparent that many promising minority high school graduates with excellent grade point average and scholastic achievement test scores enter college, but do not elect science and engineering fields. Further, many of the minority science and engineering students who succeed at the undergraduate level and who have the ability to do graduate level research, never consider research as a career option. NASA principal investigators report that very few graduate-level minorities are available; however, they can find minorities

at the undergraduate level and encourage them to pursue graduate degrees. Thus, the objective of this program is to build a pipeline of undergraduate minority students and ensure increased numbers for graduate studies.

In all of the above programs, NASA's ultimate goals are to encourage strong research focus and alliances between HBCUs, other minority universities, majority research universities, industry, and other Federal R&D agencies; and to help develop the resource pool of future talent that will be needed by this agency, those institutions and the Nation.

Historically black colleges and universities

The objectives of the Historically Black Colleges and Universities (HBCU) program are to increase significantly HBCU participation in NASA sponsored programs; increase and strengthen their research infrastructure, curricula and faculty capabilities; help develop a cadre of minority undergraduate and graduate science and engineering researchers at the HBCUs; and involve private sector institutions in the NASA/HBCU initiatives.

NASA will continue to sponsor, promote and encourage individual and team research and training grant projects and programs which include the participation of undergraduate and graduate students. In addition, NASA is proposing the establishment of two HBCU-Space Science and Engineering Centers of Excellence (SSECE) to upgrade scientific and technical research and development capabilities of a few of the most productive HBCUs. This initiative will expedite the strengthening of the institutions' research infrastructure and curricula, increase the number of minority faculty and students engaged in meritorious scientific research, and help the universities become renowned as major centers of excellence in their chosen areas.

In FY 1988, 31 HBCUs participated in NASA sponsored programs; and they were the recipients of 78 research and development and 22 training grant awards. A total of 24 faculty fellows, 232 graduate and 465 undergraduate students participated in the NASA/HBCU efforts. The HBCU program is funded by this program and other awards that may emanate from programs and installations during the fiscal year.

In FY 1990, in addition to continued funding for HBCUs, NASA plans to select one or two HBCU-SSECEs. At least a five year commitment to each center is anticipated. A comprehensive annual evaluation of both center program efforts will be conducted to determine the effect on constituent users; and the results will be utilized for program modifications for subsequent funding periods or for decisions concerning further expansion.

Other minority universities

NASA will establish and/or expand its relationships with universities with significant populations of minorities who are traditionally underrepresented in science and engineering. It is anticipated that these other universities will be selected on the basis of a combination of factors, such as science and engineering curricula and accreditation, research capabilities, and significant numbers of underrepresented minority students and faculty. These other univer-

sities will be encouraged to increase their participation in NASA's research and technology, educational opportunities, and services.

FY 1990 funding will provide initial research grants for a few selected universities other than HBCUs to expedite the strengthening of their research infrastructure and curricula and to increase their minority faculty and students engaged in meritorious scientific research.

Graduate student researchers program (underrepresented minority focus)

The objectives of this program are to enhance the development of underrepresented minority talent in an effective way so as to utilize the potential of this Nation's diverse citizenry; and to increase the size of the resource pool of research skills that will be needed to meet aerospace and other technological objectives of the future. Principal investigators who have NASA research grants, and a need for further student involvement, will be encouraged to seek out talented underrepresented minority students and involve them in their NASA research projects. The underrepresented minorities who are the special focus of this program are Blacks, Hispanics, American Indians and Pacific Islanders. They must be enrolled in masters or doctoral programs in engineering, physics, mathematics, computer science, biology, or other disciplines of interest to NASA in aeronautics, space and life sciences.

In FY 1988, the second year of the program, an additional 48 underrepresented minority students were selected to make a total of 108 participants in the program. These included 51 Blacks, 47 Hispanics, 6 American Indians and 4 Pacific Islanders.

The funds provided in FY 1990 will be used to continue the current program and allow for an increase in students' stipends.

Undergraduate student researchers program

This new program will identify freshman-level, high potential, underrepresented minority students attending universities and majoring in science and/or engineering; and will serve as a feeder to the Graduate Student Researchers program (underrepresented minority focus). Identified students will receive tuition support; will be monitored, tutored, and nurtured; and by their junior year, will become research assistants working with principal investigators at their universities on NASA sponsored research. The primary objective is to encourage talented underrepresented minorities to choose, as a career option, graduate level studies in science and engineering.

The funds provided in FY 1990 will be used to initiate the undergraduate student researchers program.

SPACE GRANT COLLEGE AND FELLOWSHIP PROGRAM

FY 1990 BUDGET REQUEST \$5,000,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

Space grant college and fellowship:

1990 budget request	\$5,000
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Enacted in NASA's FY 1988 Authorization Act (P.L. 100-47), the National Space Grant College and Fellowship program was designed to broaden the base and enhance the capabilities of the university network capable of contributing, through research, education and public service, to the increased utilization of space and its resources.

The objectives of the program are to:

- (1) Increase the understanding, assessment, development, and utilization of space resources by promoting a strong educational base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques;

- (2) Utilize the abilities and talents of the universities of the Nation to support and contribute to the exploration and development of the resources and opportunities afforded by the space environment;

- (3) Encourage and support the existence of interdisciplinary and multidisciplinary programs of space research within the university community of the Nation, to engage in integrated activities of training, research and public service, to have cooperative programs with industry, and to be coordinated with the overall program of the National Aeronautics and Space Administration;

- (4) Encourage and support the existence of consortia, made up of university and industry members, to advance the exploration and development of space resources in cases in which national objectives can be better fulfilled than through the program of single universities;

- (5) Encourage and support Federal funding for graduate fellowships in fields related to space; and

- (6) Support activities in colleges and universities generally for the purpose of creating and operating a network of institutional programs that will enhance achievements resulting from efforts under this title.

The Space Grant College and Fellowship program is composed of three complementary elements. Designated "space grant colleges/consortia" form the centerpiece. The space grant designation will recognize preeminent institutions which are substantially involved in a broad spectrum of NASA research, offer advanced study in aerospace fields, and are significantly involved in related public service. Designation will be based on the institution's plan to network with the broader higher education community, establish cooperative relationships with industry and develop innovative public outreach. Designated schools will be initially funded at \$150,000 and are expected to provide matching funds. The second element, the grant program, enables all universities to participate in the Space Grant Program. Grants will be available to meet unique aerospace challenges or to develop institutional capability. The third element, the Fellowship program, will provide a means to meet the critical needs for well trained aerospace engineers and scientists by providing universities selected in the previous two elements, funding for undergraduate and graduate fellowships.

Funding in FY 1990 will provide for phasing in the elements of the Space Grant College and Fellowship program. Through a merit review process, universities will be selected and designated as

"Space Grant Universities/Consortia." The Space Grant program will be implemented to begin to broaden the base of universities involved in space related research. The fellowship program will also be implemented in FY 1990.

TRACKING AND DATA ADVANCED SYSTEMS

FY 1990 BUDGET REQUEST 19,900,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

Advanced systems:	
1989 current estimate.....	\$18,800,000
1990 budget.....	19,900,000

The objective of the advanced Systems program is to study and develop new higher performance tracking and data handling capabilities which will address planned future mission requirements and will provide improved cost-effectiveness and reliability for overall support of the total mission mix.

This activity is a small but vital part of the total Office of Space Operations program. Advanced Systems programs continue to focus on assessing and employing technological advances in telecommunications, electronic microcircuitry, and computer sciences. Such effort is essential for the cost-effective application of new technology and for planning future mission support capabilities. Ongoing work includes the investigation of the total data transfer and processing needs of upcoming missions and studies of ground systems and telecommunication links to determine design approaches, and overall tradeoffs for the lowest life cycle costs to support future space missions.

Activities planned for FY 1990 include efforts to obtain location accuracies at the decimeter level for Earth-orbiting spacecraft, which would make possible a new class of high precision Earth observatory missions on the Space Shuttle, Space Station, and on free-flying spacecraft. Work will continue on the development of extremely precise radiometric techniques for determining angular direction of future planetary missions to an accuracy of five nanoradians. Such improvements typically lead to improved spacecraft navigation and the conduct of science experiments not previously possible. Studies will continue on ground-based navigation strategies, analyses, and demonstrations for Galileo, Ulysses and Mars Observer.

Efforts to improve communications between the ground and spacecraft will continue in such areas as the use of millimeter wave frequencies on large diameter antennas; development of more efficient transmitters and highly reliable, low noise telemetry receivers; development of a K-Band terminal for TDRSS-user spacecraft; and, antenna feed systems capable of multiple frequency operation, including millimeter waves. Such improvements in space-to-ground communications can benefit future missions by increasing the amount and quality of the data returned. Optical tracking and communications technology to meet telecommunications needs in the decades ahead will also be investigated both for cost-performance advantages over microwave technology and for potential in space data relay applications.

Future high-rate image data storage and processing requirements for Earth-orbital missions are expected to increase from a current peak use of 85 megabits per second to 300 megabits per second in the Space Station era. These requirements result from high-resolution sensors, such as multispectral scanners and synthetic aperture radars, which will be transmitting more data than previous instruments. New techniques and systems will be studied and developed for the storage, processing, and transmission of these high data rates. These studies and developments include new techniques for signal coding and decoding, optical disk buffering and storage, automated distribution and processing of high volume data, improved man-machine interfaces, high-speed modulators/demodulators, and a communications network using an optimal mix of fiber optics, satellites, and local area networks to distribute data to processing centers and users.

Investigations will continue on developing more efficient mission operations control center facilities and providing for the necessary real-time interaction between the ground-based experimenters and their spaceborne experiments. Other investigations are being carried out in the area of expert systems applications, greater use of distributed command terminals, and the performance of orbit and attitude computations onboard the spacecraft.

SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Shuttle production and operational capability	\$1,128,200,000	\$1,305,300,000
Space transportation operations	2,390,700,000	2,732,200,000
Space and ground networks, communication and data systems	945,300,000	1,102,100,000
Total	4,464,200,000	5,139,600,000

SPACE TRANSPORTATION SYSTEM PROGRAM

FY 1990 BUDGET REQUEST \$4,037,500,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Shuttle production and operational capability	\$1,128,200,000	\$1,305,300,000
Space transportation operations	2,390,700,000	2,732,200,000
Total	3,518,900,000	4,037,500,000

Now that the Space Shuttle has safely returned to flight, the primary program objective of the current activity in the Space Transportation System is to conduct all future flights in a safe and reliable manner and to ensure the establishment of necessary capabili-

ties to meet the manifested flight rate. Total flight requirements will be satisfied with a mixed fleet employing the Space Shuttle and expendable launch vehicle services. The Space Shuttle is the key element of a versatile Space Transportation System (STS) that is available to a wide variety of national users and certain international users. The Space Shuttle is the first reusable space vehicle and is configured to carry many different types of space apparatus, spacecraft scientific experiments, and national security payloads. In addition to transporting materials, equipment and spacecraft to orbit, the Shuttle offers unique capabilities that cannot be achieved with Expendable Launch Vehicles (ELV): retrieving payloads from orbit for reuse; servicing and repairing satellites in space; transporting humans to and returning them safely from space; operating and returning space laboratories; and performing rescue missions.

Shuttle Production and Operational Capability provides for the national fleet of Shuttle orbiters including the replacement orbiter which was fully funded in FY 1987. This budget elements also provides for equipment to outfit launch site and flight operations facilities, production tooling, development of an Advanced Solid Rocket Motor (ASRM), and related support activities necessary to provide the capability to safely increase and sustain a Shuttle flight rate up to 14 per year. Shuttle production also provides for the establishment of a logistics system, including an inventory of spare parts and assemblies, to support the operations flights at the 14 per year rate.

This line item contains the following major subdivisions: Orbiter Operational Capability, Propulsion, and Launch and Mission Support. Orbiter Operational Capability includes orbiter design modifications and system improvements, mission kits, procurement of a spares inventory for the operational orbiter fleet, necessary safety modifications identified by the NASA investigation and the Rogers Commission during the post-Challenger accident review process, and continuation of work started in FY 1988 on an Extended Duration Orbiter capability (EDO). Included in the spares inventory is the manufacture of key structural assemblies that also serve to maintain the capability to produce future orbiter vehicles. Propulsion Systems provides for Space Shuttle Main Engines (SSMEs), External Tank (ET), Solid Rocket Booster (SRB) design improvements, safety modifications, capability investments, rate tooling and development of an Advanced Solid Rocket Motor (ASRM). Launch and Mission Support provides for Johnson Space Center (JSC) mission operations capability development, establishment of an inventory of crew equipment, system-wide capability improvement and equipment provisioning and ground support equipment for the launch and landing facilities at the Kennedy Space Center (KSC).

Space Transportation Operations provides the standard operational support services for the Space Shuttle and Expendable Launch Vehicle services for NASA payload requirements. Within Shuttle Operations, flight hardware is produced, refurbished and repaired; and manpower, propellants, and other materials are furnished to conduct and support both flight and ground operations. Operations funding also provides for replacement of spares inventory for both flight and ground support hardware as it is consumed or damaged as a result of flight related activities. The launch

schedule calls for five flights in FY 1989, nine flights in FY 1990, and nine flights in FY 1991. The Shuttle Operations programs provides for the launch of NASA missions, as well as missions for DOD, other U.S. Government Agencies and certain commercial and international users on a reimbursable basis. A limited number of foreign and commercial launches are planned based on policy decisions prior to introduction of the mixed fleet policy.

The Expendable Launch Vehicle plan provides launch services for unmanned civil U.S. government space missions not requiring the Space Shuttle's unique capabilities. Initially, expendable launch vehicle services will be procured for selected high priority missions previously manifested on the Space Shuttle. Consistent with the Competition in Contracting Act, expendable launch vehicle services will be acquired from the U.S. private sector when possible.

The Shuttle Production and Operational Capability budget provides current funding in three areas: Orbiter Operations Capability, Propulsion, and Launch and Mission Support. The primary thrust of the current effort in orbiter operations capabilities is to complete the development and continue implementation of improvements to key orbiter subsystems such as the auxiliary power unit (APU) and inertial measuring unit (IMU) and safety modifications like the crew escape system and gaseous oxygen flow control valve. In addition, the logistics program continues to procure hardware to establish a spares inventory and equipment for a centralized depot repair capability to fully support the flight program. Activities to provide a new set of structural spares will be initiated in FY 1989. Work continues on the Remote Manipulator System to upgrade a test article to flight status. Work on an Extended Duration Orbiter (EDO), which will extend the orbiter on-orbit stay time beyond the current 10 day capability will be continued. Private sector financing will be explored for selected elements of this program.

The Orbiter Replacement was fully funded in FY 1987. A contract was signed with Rockwell International on August 1, 1987, to produce a replacement orbiter for Challenger using existing structural spares. This replacement orbiter, needed to restore the Shuttle fleet to a full operational level, will be delivered to KSC in April 1991.

Development and life certification of the Space Shuttle Main Engine (SSME) is continuing in support of the flight and ground test program. Design modifications on the high pressure pumps and the hot gas manifold are directed at increasing the SSME operating margins, reducing the SSME operating costs, and determining the hardware life and replacement requirements through a certification extension test program. A major near-term effort is to continue to develop design improvements to the high pressure turbopump blades and bearings to enhance the operating margins and extend their operational life. The long range is to replace the high pressure turbopumps with redesigned pumps from another source. A contractor was selected in 1986 for this effort and full-scale development testing is planned to start in 1991. Redesign of the hot gas manifold is continuing with the design goal of improving flow conditions which will extend engine life by decreasing systems re-

sistance and reducing pump loads. The alternate source turboprops will be introduced into the fleet during the early 1990's and the manifold changes will be implemented during the mid-1990's. The SSME program also includes an advanced technology effort which will provide a technology test bed for detailed SSME environment characterization, and will evaluate potential SSME component and system level improvements, as well as evaluate technical advances arising from the Office of Aeronautics and Space Technology's Space Research and Technology program.

The redesign of the solid rocket motor to resolve deficiencies in the previous design was completed in FY 1988. Flight data will be subjected to detailed analysis in FY 1989 to thoroughly assess the redesign. Production streamlining activities are continuing on the solid rocket booster. In FY 1989 development of an ASRM will be initiated. The ASRM will enhance reliability and safety by eliminating the redesigned SRM constraint of maximizing utilization of existing hardware. Changes in configuration, design details, and materials may be employed to meet more stringent design requirements and enhance safety margins. Production processes will be examined to use the latest applicable technology and automation to enhance reliability and producibility. Significant performance increases are also expected with the ASRM.

At KSC, modifications to major facilities and launch site equipment are continuing to provide for more efficient and reliable launch processing. For example, the Launch Complex 39 permanent weather protection modifications on Pad A will be completed in FY 1989. Additionally, the third mobile launch platform is scheduled to be activated in FY 1989. Other efforts underway include procurement of the Digital Operational Intercom System (OIS-D), extension of the Launch Equipment Test Facility (LETf) to support testing of the facility modifications, incorporation of fiber optics to improve KSC on-site communications between facilities and upgrade of the Orbiter Modification and Refurbishment Facility (OMRF) into an Orbiter Processing Facility (OPF) configuration.

At JSC, modifications to on-going activities have been approved to satisfy post-Challenger accident program requirements. Weather prediction and reporting capabilities are being expanded and the capabilities of contingency landing sites are being enhanced. Readiness of those landing sites associated with polar orbit missions has been deferred consistent with the deferral of the Vandenberg launch site activation. In addition, fidelity and reliability improvements to the training simulators are being given high priority with host computer replacement activity near completion and simulator subsystem replacement continuing.

The Shuttle Operations budget provides funding in three principal areas: Flight Operations, Flight Hardware, and Launch and Landing Operations. Flight Operations includes training, mission control, flight operations planning, payload and systems analytical integration, mission analysis, flight software, postflight anomaly resolution, orbiter sustaining engineering and launch support services.

Flight Hardware includes the replenishment of spares inventory, and repair and refurbishment of orbiter and SSME flight hard-

ware, procurement of external tanks and the interface hardware with the orbiter, refurbishment and manufacturing of solid rocket motors and booster hardware, as well as engineering and logistics support for external tank/solid rocket booster/main engine hardware elements; and maintenance and operation of flight crew equipment. The funding for the external tank and solid rocket motors and boosters includes long lead procurements of raw materials, subassemblies, and subsystems required to sustain production as the flight rate increases.

The Launch and Landing Operations budget provides funding for processing the elements of shuttle flight hardware as they flow through the ground processing stations at KSC. The Shuttle Processing Contractor (SFC), in conjunction with the Base Operations Contractor (BOC), provides all Shuttle vehicle testing, checkout, servicing, modification and launch processing functions. The Payload Ground Operations Contractor (PGOC) provides processing for all STS payloads from their arrival at KSC through Shuttle integration.

The Expendable Launch Vehicles portion of the mixed fleet plan has been developed as a result of an assessment of NASA's Space Transportation requirements after the Challenger accident. This assessment concluded that several U.S. Civil Government spacecraft should be launched on ELV's in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The plan is being implemented in phases. First, NASA plans to procure launch services through directed procurement for missions which require launching by 1991. The missions, under this first phase, are selected high priority missions previously manifested on the Space Shuttle. After the initial phase, the plan is to procure launch services from the private sector on a competitive basis to the maximum extent feasible for identified future requirements.

SHUTTLE PRODUCTION AND OPERATIONAL CAPABILITY

FY 1990 BUDGET REQUEST \$1,305,300,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Orbiter operational capability	\$281,800,000	\$237,000,000
Propulsion systems.....	582,200,000	727,300,000
Launch and mission support.....	264,200,000	341,000,000
Changes and systems upgrading		
Total	1,128,200,000	1,305,300,000

The objectives of this program are to provide for the hardware and modifications needed to support the Space Transportation System flight manifest, the completion of the national fleet of Shuttle orbiters, including building a replacement orbiter for the Challenger; the development and production of an Advanced Solid Rocket Motor (ASRM) and other propulsion systems; development

of launch site capabilities; and an Extended Duration Orbiter (EDO) capability.

With the loss of Challenger in January 1986, the orbiter fleet was reduced to three vehicles pending delivery of a replacement orbiter. The current orbiter fleet includes Columbia, the orbiter developed and flown on four test and evaluation flights, and two orbiters of a lighter-weight configuration, Discovery and Atlantis. The budget provides funding for necessary improvements, hardware fixes and mission kits for the orbiter fleet to satisfy flight requirements. In addition, the Kennedy Space Center is managing the completion of the orbiter logistics capability and is continuing the procurement of spares needed to support the flight rate build-up. The EDO development is also included to increase on-orbit stay time in order to improve the Shuttle capability to support payload requirements. Current planning is to explore potential sources of private financing for development of selected elements of this program.

Propulsion systems provide for the production of the Space Shuttle Main Engine (SSME), the development of the capability to support operational requirements established for the SSME, SRB, and ET, and the development of an ASRM. The SSME program includes: production of main engines necessary for the orbiter fleet and a spares inventory, ground testing in support of engine development, anomaly resolution and product improvement, and advanced development efforts to improve operating margins.

SRB production and capability development activities include: the reclamation of production verification and 51-L configuration solid propellant motors; investigation of returned flight hardware; procurement of tooling and equipment to support flight rate; and selected studies to continue investigative, analytical, and problem-solving activities.

In FY 1989, a contractor will be selected to develop an Advanced Solid Rocket Motor (ASRM) for delivery in 1994. The program will include the design, development, test, and evaluation of the ASRM. NASA is examining options for private financing of the production facility for this project.

Launch and Mission Support provides for the required investment in Launch Operations and Flight Operations capability to meet STS program objectives, which include supporting a safe flight rate. At KSC, reactivation of launch pad A will complete a second line of facilities allowing simultaneous processing and checkout of orbiters and associated flight hardware from landing through launch. Additional facility and support equipment are being procured to sustain the flight rate capability. At JSC, mission support provides collateral hardware, principally the extra-vehicular maneuvering units (EMU), while mission operations capability provides for improvements in the flight support systems. The flight support systems funded by this budget include training and carrier aircraft, additional landing aids and runway end barriers at the primary and contingency landing sites, and replacement/upgrade of equipment in the mission support complex including the Shuttle Mission Simulator and the Mission Control Center.

ORBITER OPERATIONAL CAPABILITY

	1989 current estimate	1990 budget request
Orbiter	\$155,800,000	\$157,500,000
Extended duration orbiter	20,000,000	25,000,000
Systems integration	30,500,000	9,000,000
Orbiter spares	55,200,000	30,300,000
Structural spares	20,300,000	15,200,000
Total	281,800,000	237,000,000

Orbiter production activities include the development and implementation of hardware, software, and procedures modifications identified by the Rogers Commission and the post-Challenger accident review process to improve safety and appellation margins. Also, work continues on improvements to achieve greater operational capabilities, reduce operational costs, and meet system requirements. These improvements include upgrading the general purpose computers (GPC), inertial measurement units (IMU), and auxiliary power units (APU). The brake and the nose wheel steering systems are undergoing modifications to improve landing performance. In addition to these system changes, there are numerous mission and modification kits required for specific flights and payloads. Also included will be the work necessary to continue development of a 16 day extended duration orbiter (EDO) capability and initial efforts for further extension up to 28 days. EDO will be developed using private financing if key safety and integration issues can be successfully resolved.

The procurement and fabrication of the orbiter spares inventory is ongoing. A concerted effort has been made to better define the spares requirements and production capability at various vendors. A logistics depot has been established at KSC for repair and maintenance of orbiter flight and ground support hardware. The on-site depot will reduce repair costs and shorten turnaround time by reducing requirements to return failed hardware to the original manufacturer. The depot is currently repairing and maintaining minor line replaceable units (LRU) and shop replaceable units (SRU) and is scheduled to transition to major repair activity and become fully operational by FY 1993.

The structural spares program initiated in FY 1983 provided the foundation for the production of the replacement orbiter (OV-105). It is necessary to initiate the fabrication of a new set of structural assemblies to replace those used in the production of OV-105. This effort, to begin in FY 1989, will provide a minimum capability to produce another vehicle in addition to providing additional hardware for inventory. Structural assemblies include the wings, aft thrust structure, engine compartment, crew module (including the nose and cockpit), mid and aft fuselage sections, payload bay doors, vertical tail, and the orbital maneuvering system pods.

Orbiter funds provide for the completion of previously approved systems improvement programs, necessary safety modifications identified as a result of the Challenger accident review process, and the engineering analysis and integration capabilities to support the

flight rate. Orbiter funding also provides for similar work on orbiter support hardware such as the remote manipulator system. In FY 1990, work on the 16 and 28 day EDO capability will continue with possible participation of private sector financing if safety and integration issues can be resolved.

The development, qualification and production of flight units for an improved auxiliary power unit (APU) and the upgrade of the general purpose computers (GPC) will be completed. The improved APU will have longer life and higher reliability and will require substantially less ground servicing. This configuration will preclude recurrence of problems which have occurred on prior flights such as the formation of wax due to the mixing of lube oil and fuel. The new GPC will add memory and increase operating speed in order to resolve the operational limitations of the current hardware and will result in a more reliable system.

Orbiter funding also covers systems integration of all redevelopment analyses and hardware changes, as well as procuring orbiter support items.

The EDO provides for the development of a cryogenic pallet kit to extend the on-orbit stay time in order to provide significantly greater time for payloads to complete their mission objectives. Cryogenic pallets will accommodate tank sets needed to supply the fuel cells with additional reactants needed to generate electrical power for the added time on-orbit. The program should be completed in FY 1992 with the modification of an existing orbiter. Efforts on the 28 day EDO will start in FY 1989 which may lead to development of the expanded capability in FY 1990. Issues under evaluation include orbiter auto-land requirements, the effect of long-duration space flight on crew capabilities, power availability compared to other power sources, and the feasibility of privately financing some parts of the EDO.

The orbiter logistics capability program in FY 1990 is continuing the lay-in of LRU's, SRU's, and repair parts to support the flight rate buildup. The funding covers the procurement of flight hardware and ground equipment hardware for inventory as well as necessary documentation, scheduling, provisioning and maintenance training. Funding is also included to provide maintenance test equipment and special test equipment to continue outfitting the centralized depot and selected vendor repair sites. In addition, a low-level of effort to preserve the option to manufacture additional structural spares will be continued.

PROPULSION SYSTEMS

	1989 current estimate	1990 budget request
Main engine.....	\$400,500,000	\$496,600,000
Solid rocket booster.....	123,700,000	106,700,000
External tank.....	7,000,000	2,700,000
Systems support.....		
Advanced solid rocket motor.....	51,000,000	121,300,000
Total	582,200,000	727,300,000

The Propulsion Systems budget provides for the production of and continued efforts to improve operating margins for the Space Shuttle Main Engines (SSME); the implementation of the capability to support operational requirements and anomaly resolution for the SSME, Solid Rocket Booster (SRB), and External Tank (ET); and the development of the Advanced Solid Rocket Motor (ASRM). The SSME program includes the production of the main engines required for the orbiter fleet, the procurement of spare engines, ground testing operations, development and certification activities to improve operating margins, reliability and durability, and anomaly resolution capability. The SRB program includes the reclamation or replacement of reusable hardware destroyed or made obsolete by the Challenger accident redesign and subsequent ground testing of the SRB redesign, continuation of test data analyses and evaluation, completion of solid rocket motor (SRM) tooling modifications and procurement of transportation equipment to support the projected flight rate. Engineering analysis and modification of booster hardware for certification of a twenty flight use capability will continue in FY 1990. The ASRM will replace the current SRM and may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins.

The SSME program has been structured into three major elements under Shuttle Production and Operational Capability: (1) flight engine; (2) development engine; and (3) advanced development. The total SSME experience now exceeds 2,255 tests, totaling approximately 362,000 seconds of test and flight time. This experience includes 319 tests, exceeding 70,818 seconds of operation, at the full power level (FPL).

The flight engine activity includes the production of new engines, retrofit of improved hardware into the fleet, and engineering analysis of ground test and flight engine performance.

The development engine activity provides for the ground test program including hardware, propellants, and test support, and for the development, certification, and flight certification extension of improved hardware including a redesigned hot gas manifold and near-term high pressure turbopump improvements such as improved blades and bearings.

Following of the Challenger accident, the SSME program has delayed all activities associated with the operational use of FPL (109 percent). Single engine testing at these levels has continued to demonstrate margin and safety for the life certification extension test program. In addition, testing is required to demonstrate capability to support extreme abort modes which require operation at FPL. The Stennis Space Center (SSC) main propulsion test stand capability is being maintained on a minimum basis for the eventual FPL test of three clustered engines. This test will provide for a verification of the main propulsion system operations at full power level using the main propulsion system test hardware mounted in the aft end of the simulated orbiter.

The advanced development activity includes the alternate turbopump program and the technology test bed. An alternate source for high pressure turbopumps was selected in August, 1986. These alternate pumps will be designed for greater reliability and safety

margins, and longer life leading to lower operational costs. The technology test bed will provide an independent means to evaluate the technical advances arising from the development program, the alternate pump effort, and the Office of Aeronautics and Space Technology research and technology program.

The redesign of the SRB to resolve deficiencies in the previous design was completed in FY 1988. Assessment of flight data, including analysis and evaluation, will be continuing in FY 1989. There will be a continuing activity to improve tooling and procedures to enhance process control and product quality. Reclamation of reusable SRM hardware produced prior to the Challenger accident will be accomplished through static firing and refurbishment. Refurbishment of the case hardware will include modification to the re-designed configuration.

The Advanced Solid Rocket Motor (ASRM) project is intended to enhance the flight safety, reliability and performance of the Space Shuttle fleet. The ASRM will not be subject to the constraint of maximum use of existing hardware that limited changes on the recent SRM design activities. The ASRM may employ changes in configuration, design details, and materials to meet more stringent design requirements and enhance safety margins. Production processes will be examined to use the latest applicable technology and process automation to enhance reproducibility and reliability. The ASRM project also includes development and certification of asbestos free insulation necessary to insure a viable source for future manufacturing of solid rocket motors. A primary objective of the ASRM is to achieve increased payload capability with the requirement that there be no compromise to flight safety and reliability, and that the impact to other Shuttle elements be held to an absolute minimum.

During the ASRM definition studies, completed in 1988, contractors did preliminary designs of a segmented motor. Also, they provided design data on a modern, automated production facility to maximize material and process controls for enhanced reliability. Development is scheduled to begin in the second quarter of FY 1989 with the selection of a Phase C/D contractor. The ASRM is planned to be ready for first flight in FY 1994.

Achievement of the planned Space Shuttle flight rate of up to 14 launches per year requires continued investment in improved propulsion systems and capabilities. The SSME program will continue the production of flight hardware and the development activities including necessary improvements to the current configuration and the alternate turbopump programs. The SRB funding will primarily focus upon continued evaluation and analysis of flight data to thoroughly assess the redesign. In addition, efforts will continue on improvements to the solid rocket motor manufacturing process and the reclamation or replacement of pre-Challenger reusable hardware and modification of booster hardware necessary to obtain 20 flight use capability. The External Tank program supports the production of tanks with acquisition of off-the-shelf test and manufacturing support equipment.

The Request for Proposal (RFP) for the development phase of the ASRM was issued in August 1988. One contractor will be selected for development with contract start anticipated during the spring

of FY 1989. The development program is anticipated to extend for five years with the first flight in late 1994. The scope of the development will include modification or acquisition of facilities, the development and test of the new design, and production of verification units. The ASRM development is comparable in scope and complexity to that of the SRM, while the technological base is more mature than that at the start of the SRM project.

LAUNCH AND MISSION SUPPORT

	1989 current estimate	1990 budget estimate
Launch site equipment.....	\$109,400,000	\$98,500,000
Mission support capability.....	42,100,000	75,600,000
Mission operations capability	112,700,000	166,800,000
Total	264,200,000	341,000,000

This activity supports the development of launch and mission support capabilities, principally at the Johnson Space Center (JSC) and Kennedy Space Center (KSC). The launch site equipment budget provides the capability to support processing and checkout of up to three orbiters in flow and sustain the operational launches at KSC. With the reactivities on Pad A in FY 1990, two complete lines of facilities will be in place to support parallel processing. A third mobile launch platform will be reactivated in FY 1989 and the orbiter modification and refurbishment facility (OMRF) will be fully outfitted into a third orbiter processing facility utilizing support equipment from the Vandenburg launch site. Launch site equipment also provides for the replacement and upgrade of existing ground support systems due to obsolescence or increasing flight requirements. In addition, funds are provided to improve capabilities including the automated data management system for launch processing documentation recommended by the Rogers Commission.

Funding has been included for upgrading landing aids for end of mission and contingency/abort landing sites. Capability improvements have been added for weather prediction and information handling to improve systems monitoring, notably for anomaly tracking. Funding for a preflight adaptor trainer has also been added to help prepare the crews for a weightless environment. Consistent with the recommendations of the Rogers Commission, improvements are being made in simulation training including new host computers, interface hardware, and simulator subsystem replacement. Critical improvements in simulation fidelity will be accommodated with the expanded capacity of the new hardware. Reliability required for the longer integrated simulations, and associated maintenance cost will also be substantially improved with these replacements. Other activities include implementing required modification and upgrades on the T-38 proficiency aircraft and producing a fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft. Procurement of additional extravehicular mobility units and associated improvements are also included.

In FY 1990, Launch Site Equipment includes activities to improve the capability to support the flight rate requirements at KSC. These include development of the automated data management system to improve the paperwork flow and traceability of launch processing, continuation of the replacement of Apollo era internal communications system with a digital system using fiber optics cabling, upgrade of the orbiter modification and refurbishment facility to an orbiter processing facility, replacement equipment for the launch processing system, extension of the launch equipment test facility (LETF), reactivation of Pad A and enhancement of equipment at contingency landing sites. Continued identification, replacement and upgrading of obsolete ground processing and support equipment will be accomplished.

Mission support capability funds are required to establish an inventory of crew equipment, principally additional extravehicular mobility units (EMU), to support the flight rate. STS operations effectiveness work and other support functions continue to support STS program-wide requirements including flight safety, mission success, and rate capability.

Mission operations capability funding in FY 1990 provides for completing replacement of the host computers and selected critical items for the Shuttle training simulators in addition to replacement of ADP and other hardware in the Mission Control Center. Continuing projects include developing and implementing the Flight Analysis and Design System (FADS), Program Compliance Assurance Status System (PCASS), and the "swing" Flight Control Room (FCF), as well as improvements to weather prediction, information handling, mission control systems, and contingency landing sites. Also included is the continued development of a preflight adaptor trainer to prepare the crew for a gravity-free environment and the ongoing aircraft modifications for the fourth Shuttle Training Aircraft and a second Shuttle Carrier Aircraft.

SPACE TRANSPORTATION OPERATIONS

FY 1990 BUDGET REQUEST \$2,732,200,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Flight operations	\$685,700,000	\$772,600,000
Flight hardware.....	1,112,700,000	1,236,500,000
Launch and landing operations.....	506,800,000	553,600,000
Shuttle operations.....	2,305,200,000	2,562,700,000
Expendable launch vehicles and services	85,500,000	169,500,000
Total	2,390,700,000	2,732,200,000

Space Transportation Operations provides launch services to NASA payloads using a mixed fleet approach of both the Shuttle and Expendable Launch Vehicles. Launch services are also provided, on a reimbursable basis, to the Department of Defense, other civil agencies, and certain commercial and international users. The Shuttle program launch schedule is based on five flights in FY

1989, nine in FY 1990 and nine in FY 1991. The ELV planning reflects use of a mix of launch systems based on individual payload requirements.

The Space Shuttle has demonstrated a broad range of capabilities including deployment of spacecraft and their upper stages, satellite repairs, satellite retrieval, operations using the remote manipulator, integral scientific experimentation using Shuttle and Spacelab systems, and extravehicular activity operations. These capabilities provide a unique opportunity to enhance the scientific return of many payloads and the Shuttle will remain the mainstay of NASA's launch capability. The major program elements of Shuttle Operations are Flight Operations, Flight Hardware and Launch and Landing Operations. These elements provide for the standard service operation of the Shuttle including preflight preparation activities, procurement and refurbishment of flight hardware and maintenance and operation of equipment and facilities necessary to support all phases of the Shuttle flight process.

The Flight Operations activity is divided into three major elements: mission support, integration, and support. Mission support includes training, flight operations activities and a wide variety of planning activities ranging from operational concepts and techniques to detailed systems operational procedures and checklists. Integration includes launch support services and sustaining engineering for orbiter systems, cargo analytical integration, and systems integration. The support element includes systems support activity at JSC such as aircraft operations, engineering support, and support to the National Space Transportation System (NSTS) program office. Shuttle system support at Headquarters and the Marshall Space Flight Center and Stennis Space Center is also included.

The Flight Hardware program element provides for: the procurement of external tanks (ET) and solid rocket booster (SRB) elements including motors, booster hardware, and solid propellants; replenishment of spare parts inventory and repair of the reusable Space Shuttle Main Engine (SSME), orbiter and crew equipment; ET disconnects, logistics support for the orbiter ET, SRB, and SSME flight hardware elements; and maintenance and operations of flight crew equipment. Included in the funding request for tanks and boosters are the long lead time raw materials, subassemblies, subsystems and additional ground testing of the redesigned Solid Rocket Motor (SRM) necessary to sustain and verify the production of elements in a manner consistent with the flight rate requirements.

Launch and Landing Operations provides for the prelaunch preparation, liquid propellants, launch, and landing operations of the Shuttle and its cargo.

In addition to being the primary launch vehicle for NASA missions, the Shuttle provides launch support to approved payloads on a reimbursable basis. Because of the Challenger accident, however, there are currently \$12.4 million in FY 1989 and no planned reimbursable funds for Shuttle Operations in FY 1990.

The Expendable Launch Vehicles/Mixed Fleet plan was initiated after the Challenger accident as a result of an assessment of NASA's space transportation requirements. This assessment

showed that several U.S. Civil Government spacecraft should be launched on ELV's in order to provide increased access to space, to assure continuity of space operations, and to enhance mission flexibility. The missions currently planned for launch on ELV's are spacecraft requiring West Coast launches and selected East Coast launches which do not require the Shuttle's unique capabilities and can transition to ELV's without significant impact to the spacecraft.

FLIGHT OPERATIONS

	1989 current estimate	1990 budget request
Mission support	\$230,500,000	\$247,500,000
Integration.....	268,800,000	300,300,000
Support.....	186,400,000	224,800,000
Total	685,600,000	772,600,000

Flight operations is divided into three major areas of activity: mission support, integration, and support. Mission support includes a wide variety of preflight planning, crew training, and operations control activities. The planning activities range from the development of operational concepts and techniques to detailed systems operational procedures and checklists. Tasks required for each flight include flight planning, preparation of systems and software handbooks; establishment of flight rules, detailed crew activity plans and procedures; development and implementation of the mission control center (MCC) and network system requirements for each flight; and operations input to the planning for the selection and operation of Shuttle payloads. Specific flight planning activity encompasses the flight design, flight analysis, and software activities. Flight design products include conceptual flight profiles and operational flight profiles which are issued for each flight as well as support to the crew training simulations and flight techniques. In addition, the flight-dependent data located in the erasable memory (mission-to-mission changes) is developed in the flight design process for incorporation into the orbiter software, Shuttle mission simulator, and MCC systems. Also included are the maintenance and operation of critical mission support facilities including the mission control center, flight simulators, crew training, and flight software reconfiguration and recertification facilities.

Integration includes orbiter sustaining engineering, payload integration into the Shuttle, system integration of the flight hardware elements, orbiter launch support services to the launch site and flight development and verification software. The orbiter sustaining engineering provides all prime contractor engineering activities necessary to re-qualify each orbiter for flight including FMEA/CIL, design changes and certification reviews. The software activities include the development, formulation, and verification support of the guidance, targeting, and navigation systems software requirements in the orbiter.

Support includes base operations support to Shuttle operations and systems level support at the manned space flight centers. Base

operations support provides for operation and maintenance of aircraft for flight training, crew proficiency and the ferry requirements; engineering and supporting activities for the orbiter, crew equipment, and flight operations systems; and support to the NSTS program office.

Currently, the resources for Flight Operations are focused upon providing the flight products necessary to support the manifested flight rate, fixing a backlog of system discrepancies and incorporating a large number of changes to ground systems hardware, software, and procedures including those resulting from the ongoing process of analysis and decision-making in the wake of the Challenger accident. Flight preparation, training of ground and flight crews (including system-wide integrated simulations), and other functions are being carried out. These efforts are critical to the safe operation of the Shuttle and significant emphasis is being placed on ensuring that the flight products and crew training satisfy revised and more stringent operational requirements.

The Flight Operations portion of the Shuttle Operations budget continues to support that activity predominately associated with the effort at JSC to plan for and conduct STS missions from launch to landing. The functions in Mission Support and Support are essentially the same as in the past: to maintain and operate all the ground facilities necessary for flight preparation and execution, and to train the flight and ground controller crews; to maintain and operate aircraft for proficiency training and orbiter ferry requirements and to perform the mission planning necessary for each mission. These activities will support the increase in flights to 9 in FY 1990. In addition, independent cargo hazard analysis will be expanded and funds are required to support a reduction in planned DOD secure flight support.

Flight Operations also includes the sustaining engineering required to integrate all flight and ground elements and to assure systems safety and integrity; the analytical integration of the payloads into the orbiter and the planning to assure compatibility and verification of interfaces; and support of crew operations and training programs. Orbiter engineering manpower continues the required support of procedure and hardware modifications resulting from the FMEA/CIL reviews in addition to the sustaining engineering activities that ensure maintainability, reliability, and anomaly resolution during operations. Integration efforts will support the increase in flight activity in FY 1990 as development efforts funded under Orbiter Operational capability are completed.

FLIGHT HARDWARE

	1989 current estimate	1990 budget request
Orbiter.....	\$301,300,000	\$351,800,000
Orbiter spares.....	(116,400,000)	(167,600,000)
Solid rocket booster.....	516,800,000	537,000,000
External tank.....	294,600,000	347,700,000
Total.....	1,112,700,000	1,236,500,000

The Flight Hardware program element provides for the procurement of External Tanks (ET), the manufacturing and refurbishing of Solid Rocket Booster (SRB) hardware and motors; and operational support to the Orbiter elements including the orbiter, external tank disconnects, main engines (SSME) and crew equipment. Included in the funding request for tanks and boosters are the long lead raw materials, subassemblies, and subsystems necessary to sustain the production of these elements in a manner consistent with the increasing flight rate. Production phasing of these elements is based on the current flight traffic model and is structured to maintain a smooth and efficient buildup of the production capability. Included also are static test firings of two production type solid rocket motors a year in order to continue verification and analysis of the SRM redesign. In the ET, production continues at a minimum level of activity necessary to retain manufacturing capability. The Orbiter line element includes replenishment of the spare parts inventory of line and shop replaceable units, the manpower for supporting the logistics operation, and the repair capability for flight hardware. Also included is the procurement of expendable hardware consumed in flight operations, field support, and maintenance of crew-related equipment as well as SSME flight support and engine overhauls. Some examples of orbiter equipment requiring logistics support are fuel cells, tiles for thermal protection, tape recorders, leading edge support structures, wheels, brakes and pyrotechnics. The crew-related equipment activities include support to preflight training and flight usage of the extravehicular maneuvering unit, emergency portable oxygen systems, radiation instruments, survival radios, closed-circuit television cameras, medical support, and food and other galley-related items.

Requirements for Orbiter spare parts consumption, repairs and logistics operations are based on projected flight rates, maintenance schedules, operational usage, repair times, and lead times to procure or repair flight hardware. The budget provides replenishment line and shop replaceable units, as well as the manpower to support the overhaul and repair activity for the orbiter, extravehicular maneuvering unit and other crew equipment. The flight equipment processing contractor (FEPC), which was initiated during FY 1986, is continuing its buildup to full capability to support the projected flight rates. Main Engine hardware provides for refurbishment and delivery of overhauled engines, replenishment or repair of engine component spares and flight support.

Flight hardware requirements activity for the SRB and ET include the procurement of the materials and labor required for refurbishment and manufacturing activities necessary to support flight requirements. The SRB project will increase flight set deliveries from 6 in FY 1989 to 9 in FY 1990. The ET will remain at the minimum delivery schedule of 4 per year through FY 1990. These projects, particularly the ET, have extended manufacturing cycles and long-lead materials procurements. As a result, a significant part of the FY 1990 funding is required to support the increased flight rates planned for subsequent years. Additionally, the first flight support motor static firing test will be conducted to monitor the consistency of production characteristics of the solid rocket

motors and to provide a data base for continuing engineering evaluations and design changes.

LAUNCH AND LANDING OPERATIONS

	1989 current estimate	1990 budget request
Launch operations.....	\$452,800,000	\$492,500,000
Payload and launch support.....	54,000,000	61,100,000
Total	506,800,000	553,600,000

Launch and Landing Operations provides for the manpower and materials to process and prepare the Shuttle flight hardware elements for launch as they flow through the processing facilities at KSC. Standard service processing and preparation of payloads as they are integrated into the orbiter are also funded by this category as is procurement of liquid propellants for launch and base support. Support to landing operations at KSC and contingency sites, as required, is also provided.

Operation of the launch and landing facilities and equipment at KSC is the primary function of the Shuttle Processing Contractor (SPC). This includes stacking and mating of the flight hardware elements into a launch vehicle configuration, verification of the launch configuration, and operation of the launch processing system prior to lift-off. Support is also provided by the SPC for booster retrieval operations, configuration control, logistics, transportation, and inventory management.

Support to Shuttle processing is provided by the Base Operations Contractor or (BOC). The BOC is responsible for operations support functions such as processing propellants, life support systems, railroad maintenance, pressure vessel certification, Shuttle landing facility and facility and equipment modifications.

Other launch support services included in this budget are maintenance and repair of the central data subsystem, which supports Shuttle processing as an on-line element of the launch processing system; range support provided by the DOD; Shuttle related data management functions such as work control and test procedures; and purchase of equipment, supplies and services not procured under the Shuttle processing contractor.

The Payload and Ground Operations Contract (PGOC) is the major contract for the payload processing activities. In Shuttle Operations, the PGOC contractor provides the standard service processing of all STS payloads into an integrated cargo prior to loading into the Shuttle. PGOC will also be the primary contractor for Spacelab and Space Station payload processing at KSC, funded under their respective budgets.

Launch operations funding in FY 1990 provides for manpower and support services necessary for processing the planned increase to 9 launches from KSC. This includes manpower to assemble the SRB's, mate the boosters and tanks, process the orbiter, mate the orbiter to the integrated SRB's and tank, process and checkout integrated flight elements through launch, retrieve the SRB's for refurbishment, and support landing of the orbiter at both the pri-

mary and contingency landing sites. Funding also supports the manpower required for sustaining engineering, launch processing system operation and maintenance, and maintenance/modification of all other Shuttle-related ground support equipment and facilities. Flight safety will continue to be emphasized through testing, engineering and quality control. Additional manpower and support services are required to operate Pad A and MLP 3 which will be activated at the start of the year.

Payload and launch support funding provides propellants for launch operations and base support, and contractor support for the assembly of individual payloads into a total cargo. This element includes providing launch site support managers to payload customers, verifying cargo-to-orbiter interface, and providing operations maintenance and logistic support to cargo support equipment (such as cargo integration test equipment and multi-mission payload support equipment) and to the payload support areas including the Vertical Processing Facility, Operations and Checkout-building, and cargo hazardous servicing facilities.

EXPENDABLE VEHICLES AND SERVICES

	1989 current estimate	1990 budget request
Small class	\$14,000,000	\$26,300,000
Medium class	46,500,000	86,200,000
Intermediate class	5,000,000	54,900,000
Large class	20,000,000	2,100,000
Total class	85,500,000	169,500,000

The Expendable Launch Vehicles/Mixed Fleet Program, initiated in 1987, will provide launch services for selected NASA payloads not requiring the Space Shuttle's unique capabilities. Under Phase I of this program, funds being provided in FY 1989 will continue to be utilized for procurement of Delta II vehicles and launch services through the DOD under the QUID PRO QUO for the Roentgen Satellite (ROSAT) and Extreme Ultraviolet Explorer (EUVE) missions. In addition, NASA is preparing a Delta vehicle for launch of its Cosmic Background Explorer (COBE) mission in mid-1989 using funds reimbursed by DOD for residual Delta vehicle hardware. Titan III commercial launch service is being procured for launch of the Mars Observer spacecraft in September 1992. NASA is also executing an exchange of residual assets from previous NASA programs for an Atlas-Centaur commercial vehicle from General Dynamics for launch of the Combined Release and Radiation Effects Satellite (CRRES) in support of a June 1990 launch. Several of the planned CRRES experiments which cannot be accommodated on the Atlas/Centaur will be launched on a Scout vehicle.

Phase II ELV launch services will be acquired by NASA competitively, whenever possible, to launch civil government payloads in four performance classes: (a) small class capable of launching payloads up to 1,000 lbs, (b) medium class capable of launching payloads up to 10,000 lbs, (c) intermediate class capable of launching payloads up to 30,000 lbs, and (d) large class capable of launching

payloads up to 40,000 lbs, or more into low Earth orbit. NASA will acquire launch services through the DOD, whenever competitive commercial launch services in a particular class are not available.

Funds are required in FY 1990 to complete procurement through the DOD under QUID PRO QUO for the launch of the ROSAT mission on a Delta II in February 1990, and continue procurement of the launch vehicle for the EUVE mission planned in FY 1991. In addition, funds are required for mission-unique hardware for the launch of the CRRE mission on a commercial Atlas/Centaur in June 1990.

Initial funding will be required for the procurement of commercial launch services for: (a) a series of projected medium-class missions starting with the currently approved GEOTAIL and WIND missions of the Global Geospace Science Project targeted for launch in FY 1992 and FY 1993 as well as for the Polar and MSAT missions targeted for launch in FY 1993; and (b) a series of Small Explorer Satellite class missions planned to be launched at a rate of two per year starting in FY 1992. These small class missions are described in a recent NASA Announcement of Opportunity of the NASA Office of Space Science and Applications dated May 14, 1988. This funding request takes into consideration the recent NASA/DOD Agreement allocating three of six Scout vehicles currently remaining in the DOD inventory to support two NASA launches in FY 1991 and one in FY 1992.

The acquisition of the Titan III commercial launch services will be continued for the Mars Observer mission scheduled for launch in FY 1992. The initial phase of mission integration services necessary for a Titan IV launch of CRAF and an intermediate class launch of SOHO in 1995 will also be initiated.

SPACE AND GROUND NETWORKS, COMMUNICATIONS AND DATA SYSTEMS

FY 1990 BUDGET REQUEST \$1,102,100,000

FISCAL YEARS 1989 AND 1990 FUNDING LEVELS

	1989 current estimate	1990 budget request
Space network.....	\$483,900,000	\$582,300,000
Ground networks.....	228,100,000	269,600,000
Communications and data systems.....	233,300,000	250,200,000
Total	945,300,000	1,102,100,000

The purpose of this program is to provide vital tracking, telemetry, command, data acquisition, communications and data processing support to meet the requirements of all NASA flight projects. In addition to NASA flight projects, support is provided on a reimbursable basis for projects of the Department of Defense (DOD), other Government agencies, commercial firms, and other countries and international organizations.

Support is provided for Earth orbital, planetary and solar system exploration spacecraft missions, launch vehicles, research aircraft, sounding rockets and balloons. Included in Earth orbital support are

the Space Shuttle, Spacelabs, and scientific and applications missions. The various types of support provided include: (a) tracking to determine the position and trajectory of vehicles in space; (b) acquisition of science and space applications data from on-board experiments and sensors; (c) acquisition of engineering data on the performance of spacecraft and launch vehicle systems; (d) reception of television transmissions from space vehicles; (e) transmission of commands from ground facilities to the spacecraft; (f) voice communications with astronauts; (g) transfer of information between the various ground facilities and control centers; and (h) processing of data acquired from the launch vehicles and spacecraft. Such support is essential for achieving the scientific objectives of all flight missions and for executing the critical decisions which must be made to assure the success of these missions.

Tracking and acquisition of data for the space projects is presently accomplished through the use of a worldwide network of NASA ground stations, and by two tracking and data relay satellites in geosynchronous orbit working with a highly specialized ground station. Ground facilities are interconnected by terrestrial and satellite communications circuits linking the spacecraft and their control centers for execution of the missions.

NASA has three basic support capabilities to meet the needs of all classes of NASA flight missions. These are the Spaceflight Tracking and Data Network (STDN), which currently supports Earth orbital missions; the Deep Space Network (DSN), which primarily supports planetary and interplanetary flight missions; and the Space Network, including the Tracking and Data Relay Satellite System (TDRSS), which will provide most low Earth orbital mission support when it becomes fully operational.

The STDN, managed by the Goddard Space Flight Center, will provide Earth orbital support until the TDRSS becomes operational. At that time the STDN phasedown will continue with the closure of several additional ground stations. The DSN, under the management of the Jet Propulsion Laboratory (JPL), provides support to geosynchronous, highly elliptical, and planetary and solar system exploration missions, as well as support to those spacecraft, now in low-Earth orbit, which are not compatible with TDRSS.

Highly specialized computation facilities provide real-time information for mission control and accommodate processing into meaningful form the large amounts of scientific, applications, and engineering data which are collected from flight projects. In addition, instrumentation facilities provide support for sounding rocket and balloon launchings and flight testing of aeronautical research aircraft.

The Space Flight, Control and Data Communications request includes the Space Network, STDN, DSN, and Communications and Data Systems elements of the program, and provides funding for: (a) TDRSS operations, spacecraft production, and launch support; (b) operations and maintenance of the tracking, data acquisition, mission control, data processing, and communications facilities; (c) the engineering services and procurement of equipment to sustain and modify the various systems to support continuing, new, and changing flight project support requirements; and (d) the spectrum

management, frequency allocation, and flight data standards support functions for NASA.

SPACE NETWORK

	1989 current estimate	1990 budget request
Tracking and data relay satellite system (TDRSS).....	\$295,800,000	\$320,800,000
Space network operations.....	34,800,000	39,600,000
Systems engineering and support.....	31,600,000	32,400,000
TDRS replacement spacecraft.....	58,600,000	44,400,000
Second TDRSS ground terminal.....	59,100,000	123,600,000
WSGT system replacement.....	4,000,000	6,000,000
Total	483,900,000	582,300,000

The Space Network consists of the Tracking and Data Relay Satellite System (TDRSS) and a number of NASA ground elements to provide the necessary services to low Earth orbital spacecraft including the Shuttle. The TDRSS, when fully operational, will consist of a three satellite constellation, including an on-orbit spare, in geostationary orbit and ground facilities located at White Sands, New Mexico. From the White Sands location, satellite and ground communication links interconnect the NASA elements of the network and remotely located user facilities.

The FY 1990 request includes funding for: repayment of the loans extended by the Federal Financing Bank for TDRSS development; maintenance and operation of the White Sands complex and other NASA elements of the network; support activities such as systems engineering, documentation and mission planning; equipment modification and replacement; competitive design studies for the next generation TDRSS; the development of an additional spacecraft to replace the TDRS lost in the Challenger accident; and the modernization of the current ground terminal and beginning implementation of a second ground terminal at White Sands.

Tracking and data relay satellite system

OBJECTIVES AND STATUS

The Tracking and Data Relay Satellite System's (TDRSS) objective is to provide communications services between user spacecraft and ground facilities. The relay satellites provide space-to-space communications to and from user satellites and relay these communications to the White Sands ground facilities which are interconnected with the other elements of the network. From their position in geostationary orbit, the TDRS's can provide nearly a six-fold increase in the orbital coverage provided by ground tracking stations and can accommodate extremely high user data rates ranging up to 300 megabits per second.

The TDRS-1 was launched in April 1983, and since that time it has supported Shuttle missions, including Spacelabs, and free flyer satellite missions such as the Solar Maximum Mission (SMM), Earth Radiation Budget Satellite (ERBS), Landsat, and Solar Mesospheric Explorer (SME). The TDRS-2 was destroyed during the Challenger accident in January 1986. TDRS-3 was successfully

launched in September, 1988, with the return of the Shuttle to flight status. The spacecraft has completed its initial checkout in an excellent manner and supported the STS-27 mission launched in December 1988. The next TDRS is scheduled for launch in the first quarter of 1989. Once this spacecraft is successfully deployed, the system will achieve full operational status and the TDRS-1 will become the on-orbit spare due to its degraded communications services capability.

The primary activity during FY 1990 will be the preparation of the fifth spacecraft for its launch. Low level assembly and test activities will be conducted on the sixth spacecraft as crew availability permits.

Under the terms of the TDRSS service contract, loans were extended by the Federal Financing Bank (FFB) to Space Communications Company (SCC), the owner-operator of the TDRSS, for program development. Under the terms of the loan agreement and assignment, NASA repays these loans directly to the FFB. In addition, NASA will make payments to SCC for service, the operation and maintenance of the White Sands complex, and for satellite construction and launch support provided during the year.

Of the amount requested in FY 1990, \$227 million is for the FFB loan repayments. The remainder of the request is for continuing spacecraft activities, service payments, and operation and maintenance of the White Sands Ground Terminal.

Space network operations

The objective of Space Network Operations is to provide for the operation and maintenance of the associated NASA ground systems and facilities which, when combined with TDRSS, provide a full array of reliable services to user spacecraft in low Earth orbit. These services are designed to function as part of an integrated operations system and perform specific functions for the Space Network.

The NASA Ground Terminal (NGT) monitors TDRSS performance, provides fault isolation monitoring for the network, and serves as the communications interface between White Sands and all other user facilities. The Network Control Center (NCC) manages and schedules TDRSS services for all user spacecraft, and the Flight Dynamics Facility (FDF) provides orbit determination, trajectory analysis, and position location for selected flight missions supported by the space and ground networks. The overall system has provided services to a variety of missions, and effort is continuing to achieve an operational configuration that will be capable of supporting the expanded workload in the early 1990's as the Shuttle flight rate increases.

The decrease of \$11.9 million from the FY 1989 budget estimate results primarily from reduced contractor support and lower than anticipated labor rates for this period.

The funding request provides for services to operate network facilities 24 hours a day, seven days per week, and for related hardware and software maintenance. Funding is also provided for a variety of support activities such as operational analysis, mission planning, simulations, user compatibility testing, and documentation.

Systems engineering and support

The objective of Systems Engineering and Support is to provide the engineering services and hardware required to sustain and modify the NASA elements of the Space Network. Engineering services are supplied primarily through support service contracts. Preparations continue to assure ground system readiness for support of Shuttle flights, including the upcoming TDRS launch, and for full network operation once the TDRSS is fully operational. There is ongoing activity to sustain system reliability for current users and preparations are underway to meet the support requirements of upcoming missions such as the Hubble Space Telescope.

Funds are requested to provide systems engineering, hardware and software maintenance, sustaining engineering support, test equipment, and vendor maintenance for specialized equipment and subsystems within the Space Network. Funds are also requested for continued software development and ongoing hardware implementation, replacement, and modification for the NCC.

TDRS replacement spacecraft

A contract has been awarded to TRW, the subcontractor for the TDRSS space segment, to provide a replacement spacecraft for TDRS-2, lost with the Challenger. The replacement spacecraft will assure TDRSS service continuity until the Advanced TDRS can be developed and deployed. The design objective is to provide a satellite functionally identical to the current satellites and fully compatible with the existing system. Modifications have been made to the original spacecraft design due to parts failure and obsolescence.

During the fourth quarter of FY 1989, the critical design review will be held, and the program emphasis will shift from design to fabrication. In FY 1990, spacecraft fabrication will be initiated with deliveries of structural components, reaction control system elements, and electronic components for both the spacecraft and its communications payload. Buildup of subsystem modules and assemblies will continue through FY 1990.

The requested funding will provide for continuation of the construction phase of the program. This phase will include completing all design activities and continued fabrication of the spacecraft bus and payload hardware. The launch readiness date of the replacement spacecraft is now under review and based on the current budget will not occur before mid-1993.

Second TDRSS ground terminal (STGT)

The objective of this program is to insure continuity of service and to minimize the potential loss of critical space assets, including science data. The existing terminal at White Sands, New Mexico, is a single point of failure for the entire Space Network, and a catastrophic failure of this terminal could result in a nearly complete loss of NASA communications and data gathering capabilities for Earth orbiting missions. In addition, the present terminal has experienced equipment failures causing temporary service outages which could have been avoided with a backup terminal.

Due to the aging of equipment, replacement of major subsystems and components in the existing terminal will eventually be re-

quired. This will necessitate an alternate means of conducting network operations while the replacement activity is underway. The addition of a second ground terminal will provide the necessary alternative means for continuing operational support while the existing terminal is down during modernization.

Because the design of the current terminal is limited to full operation of two TDRS spacecraft, a second terminal will also provide the additional flexibility to operate more spacecraft if, as anticipated, mission requirements exceed current capabilities in the mid 1990's. The General Electric Company was selected in October 1988 for final negotiations leading to award of a contract for the implementation of the STGT.

The FY 1990 funding level is required to initiate several large procurements of off-the-shelf equipment systems required early in the development of STGT for use in software development and proof of system designs. Extensive testing at the contractor facility will also be required during 1990 for compatibility with operational concepts. The purchase of equipment will ensure a more cost effective and efficient procurement process by purchasing in quantity. Equipment systems to be purchased include antennas, radio frequency receivers and transmitters, power supplies, and computer/ADPE hardware. In addition, fabrication of additional custom designed hardware systems will be initiated during FY 1990. During late FY 1990, the extensive system engineering and design efforts will culminate in a final design concept for STGT. The above activities need to occur during FY 1990 in order to meet a required completion date of late 1993.

White Sands Ground Terminal (WSGT) System Replacement

The objective of the WSGT System Replacement is to provide long term reliability and life cycle cost savings for the White Sands ground terminal operation. The Second TDRSS Ground Terminal (STGT) is planned to be operational by the end of 1993, and its advent will provide the opportunity to undertake the modernization of the WSGT system which have been in operation since 1979. The replacement systems will be identical to those in the STGT.

The replacement of the WSGT systems provides a two-fold benefit to long-term Space Network operations. First, the aging equipment and the error-prone, difficult-to-maintain architecture of the original ground terminal will be replaced with updated technology and the inherently more reliable architecture of the STGT, simplifying operations and maintenance. Second, the existence of two identical, more reliable ground terminals allows greatly reduced operational staffing through the use of common hardware and software maintenance facilities, logistics, and engineering support.

The requested funding will provide for procurement of additional STGT systems to modernize the current WSGT. This procurement will be initiated upon completion of the STGT Critical Design Review. The procurement of these systems will allow additional units to be built as part of the STGT production, thereby lowering unit hardware costs and avoiding additional nonrecurring engineering costs.

Advanced Tracking and Data Relay Satellites (ATDRS)

The objective of the program is to design, develop and competitively procure technologically advanced satellites to sustain Space Network operations. By the mid-1990's, the stock of ground spare spacecraft for the Tracking and Data Relay Satellite System (TDRSS) is expected to be exhausted. The ATDRS will provide the capability to extend network service into the 21st century and to accommodate the future mission requirements projected for this era. Initial studies are in progress and will be completed during FY 1989.

Requested funding is required to initiate the design definition (Phase B) studies. Current plans are to select several contractors in the last quarter of FY 1990 to perform ATDRS definition studies.

GROUND NETWORKS

	1989 current estimate	1990 budget request
Spaceflight tracking and data network systems implementation	\$4,500,000	\$4,400,000
Spaceflight tracking and data network operations	64,600,000	66,600,000
Deep space network systems implementation	39,700,000	63,400,000
Deep space network operations	95,700,000	103,500,000
Aeronautics, balloons, and sounding rocket support systems implementation	6,800,000	11,800,000
Aeronautics, balloons, and sounding rocket support operations	16,800,000	19,900,000
Total	228,100,000	269,600,000

The Ground Networks provide support to three broad categories of missions: Earth orbital spaceflight; planetary and solar system exploration; and aeronautics, balloons and sounding rockets. Earth orbital support is provided primarily by the Spaceflight Tracking and Data Network (STDN), a network of eight geographically dispersed ground stations. The Deep Space Network, with ground stations located at three sites approximately 120 degrees apart in longitude, provides support to the planetary and solar system exploration missions as well as Earth orbital missions not compatible with TDRSS. Aeronautical, balloon and sounding rocket research is supported by specially instrumented ranges as well as mobile systems.

Funding for the Ground Networks provides for operation and maintenance of the worldwide tracking facilities, engineering support, and the procurement of hardware and software to sustain and modify network capabilities as required to support new missions. The workload in FY 1990 will include support to the Space Shuttle and the Ulysses spacecraft launch. Magellan will begin radar mapping of Venus and Galileo will swing by Venus for its first gravity assist during FY 1990. Preparations will be underway for the FY 1992 Mars Observer planetary encounter missions and the GGS and COSTR missions. Voyager-2 encounter with the planet Neptune, in FY 1989, and ongoing missions such as Dynamic Explorer (DE), International Ultraviolet Explorer (IUE), and Solar Maximum Mission (SMM) will continue to receive Ground Networks

and/or Space Network support. Aircraft test programs will also be supported.

The STDN stations at Ascension Island, Guam, Chile, and Hawaii, and Yarragadee, Australia are planned to be phased out following the achievement of TDRSS operational status. Station operations at these sites will cease on September 30, 1989. The operation of the Merritt Island and Bermuda stations will continue; these stations will be primarily used for STS prelaunch, launch, range safety, and landing support. Some limited non-routine orbital support will also be provided.

A new advanced development antenna will be completed at Goldstone in 1990. This antenna will permit research on advanced beam waveguide techniques and enable the DSN to migrate to higher, more efficient communications frequencies such as Ka band. A new, more accurate, technique for measuring the electron content of the ionosphere will be employed during FY 1990. This measurement is critical to all groundbased navigation of distant spacecraft since it is required to compensate for the bending of radio waves as they pass through the ionosphere. This technique will use Global Positioning System satellites in conjunction with a special receiver and processor at each of the DSN complexes.

Spaceflight tracking and data network systems implementation

The Spaceflight Tracking and Data Network (STDN) systems implementation program encompasses the procurement of hardware and attendant engineering services to sustain, modify, and replace existing network capabilities to ensure reliable tracking, command and data acquisition support to NASA's spaceflight missions.

The FY 1990 request includes funds to upgrade equipment and subsystems at the Merritt Island, Florida, and Bermuda STDN tracking stations, which will continue in service after the TDRSS is operational. The request also includes funding for the replacement of obsolete, difficult-to-maintain equipment at these tracking stations and at other network facilities. In addition, the funds requested will provide for the procurement of major subsystems spare components, the replacements of older test equipment, and minor equipment modifications to accommodate changes in support requirements.

Spaceflight tracking and data network operations

The primary function of the Spaceflight Tracking and Data Network (STDN) system is to support NASA's Earth orbiting spaceflight missions, including the Space Shuttle. This network also provides launch support to NASA planetary missions, and on a reimbursable basis, spaceflight missions of other United States government agencies (NOAA and DOD), private industry, and other nations.

The STDN presently consists of eight geographically dispersed ground stations located at: Merritt Island, Florida; Kauai, Hawaii; Guam; Ascension Island; Dakar, Senegal; Bermuda; Santiago, Chile; and Yarragadee, Australia. Each of these stations, with the exception of Yarragadee, have the capability to electronically track spacecraft, send commands for spacecraft and experiment control purposes, and receive engineering and scientific data from the

spacecraft. In the case of manned flights, they also maintain voice communications for crew operations and safety and other project-related purposes. The Yarragadee, Australia, station provides only air-to-ground voice communication with the Space Shuttle astronauts.

At the beginning of FY 1990, the STDN will undergo a highly significant change from its current configuration when the Space Network achieves operational status. At that time five STDN stations will cease operations and either close or be transferred to other organizations. The stations scheduled to close on September 30, 1989 are Ascension Island; Guam; Hawaii; Santiago, Chile; and Yarragadee, Australia. The station at Dakar, Senegal will continue operating until the fifth TDRSS spacecraft is in orbit. The remaining stations at Merritt Island, Florida, and Bermuda will continue indefinitely for providing Shuttle prelaunch, launch, and landing support as well as limited orbital support.

The FY 1990 funding request provides for a full year of operation of the STDN stations at Merritt Island, Florida; Bermuda; and Dakar, Senegal. It also provides funding for closeout activities for the five stations that are scheduled to cease operations on September 30, 1989. The request includes funding for logistics support, network planning, scheduling, control center operations, engineering, documentation, and software programming support. Logistics support funded under this program is provided to a variety of users such as the Tracking and Data Relay Satellite System; the Deep Space Network; the NASA Communications Network; the Aeronautics Balloons and Sounding Rocket Support program; and spacecraft control centers.

Deep space network (DSN) systems implementation

The primary role of the Deep Space Network (DSN) is to provide the communication links between planetary and interplanetary spacecraft and the Earth. The DSN receives science and engineering data from the spacecraft and transmits navigation, command and control signals to a variety of spacecraft hundreds to billions of kilometers from Earth.

The systems and facilities required to support spacecraft at the limits of the solar system are highly specialized and include the use of large aperture antennas electronically configured in arrays to receive the extremely weak radio signals. The antennas use ultrasensitive receivers and powerful transmitters. Extremely stable time standards are required for precise navigation of distant spacecraft. Advanced data handling systems are required at both the Network Operations Control Center located at the jet Propulsion Laboratory (JPL) and the DSN complexes. Systems implementation are required to support the Magellan launch in April, 1989; the Neptune encounter of Voyager-2 in August, 1989; the Galileo launch in October, 1989; and the Dynamics Experiment on Phobos which begins in April, 1989. Preparations to support the Mars Observer, Topex, GGS, COSTR, and CRAF/Cassini missions are also underway.

The five major objectives of the DSN are as follows: (1) to provide communications links to scientific spacecraft at greater distances and to increase the capability to receive images at these distances;

(2) to increase the frequency range and data rate capability of the ground network to accommodate new deep space mission requirements; (3) to provide mission support for Earth orbiting spacecraft which are non-TDRSS compatible; (4) to provide improved navigation capabilities for precise spacecraft targeting and probe delivery; and (5) to provide emergency support to TDRSS compatible spacecraft.

Funding in the FY 1990 request provides for sustaining activities required to keep the DSN functioning in a highly reliable manner. In addition, FY 1990 funding provides for the development of new DSN capabilities to support the following missions and projects: Magellan, Mars Observer, Topex, Galileo, GGS, COSTR, and CRAF/Cassini. These capabilities include changes to the data systems at the tracking stations and the control center, the stations' radio frequency systems, and the stations' receiving systems. The transmitting power levels of the Goldstone and Arecibo radars are being increased to improve the resolution and range for the Solar Radar program studies on asteroids and landing sites.

Engineering studies will begin in FY 1990 for the first of three new 34-meter beam waveguide antenna. These three antennas will replace the oldest antennas in the network, which are now at the end of their useful lifespan. The design for the new antennas will be based upon the results obtained from the Advanced Development Antenna at Goldstone.

Deep space network operations

The three Deep Space Network (DSN) complex locations—Goldstone, California; Canberra, Australia; and Madrid, Spain—are approximately 120 degrees apart in longitude to permit continuous viewing of planetary spacecraft. Each complex has four antennas—one 70-meter, two 34-meter, and one 26-meter. The 26-meter antennas are used to support Earth orbiting spacecraft, such as the Space Shuttle. The complexes will be staffed for around-the-clock operations to support the critical 1989 deep space workload. Major new missions to be supported during this year are Magellan, the Voyager-2 encounter with Neptune, and Phobos. Final preparations will be conducted for the Galileo launch, scheduled for October 1989.

A centralized network control is located at the Jet Propulsion Laboratory (JPL) in Pasadena, California. Other DSN facilities include a spacecraft compatibility test area at JPL and a launch operations and compatibility facility at the STDN Merritt Island tracking station.

The DSN facilities are also used for ground-based measurements in support of experiments in solar system radar and in the field of radio astronomy. The ultrasensitive network antennas are being used in an attempt to learn more about pulsar high energy sources, quasars, and other interstellar and intergalactic phenomena.

The DSN operations funding provides for the maintenance and operation of network facilities and the support and engineering effort required for continuing operation of the network. The expected DSN workload in FY 1990 consists of support for Magellan, Galileo—including a Venus gravity assist, Phobos, and Ulysses, as well as ongoing support to a variety of missions. These missions in-

clude Pioneers-10 and -11; Pioneer-Venus; Voyagers 1 and 2; Active Magnetospheric Particle Tracer Explorer (AMPTE); International Cometary Explorer (ICE); Nimbus-7; Dynamics Explorer (DE); and Solar Maximum Mission (SMM), which is expected to reenter the Earth's atmosphere in 1990. The DSN will also provide emergency and backup support to the Space Shuttle, TDRSS, Hubble Space Telescope, and Cosmic Background Explorer (COBE).

Aeronautics, balloons and sounding rocket support systems implementation

The facilities of the Aeronautics, Balloon and Sounding Rocket (AB&SR) program encompass the ground support capabilities required to capture the scientific and engineering data from aircraft, balloons, sounding rockets and some Earth orbiting vehicles engaged in scientific research. The primary fixed facilities are located at the Wallops Flight Facility (WFF), the Moffett Field Flight Complex (MFFC) and the Dryden Flight Research Facility (DFRF).

The Wallops Flight Facility, under the management of Goddard Space Flight Center (GSFC), operates an extensive range at Wallops Island, Virginia, which supports aeronautics research as well as sounding rocket and small meteorological balloon launches. In 1986, a capability was established at WFF to provide tracking and data acquisition support to certain Earth orbiting satellites to supplement the capabilities of the Spaceflight Tracking and Data Network (STDN). WFF also manages the operation of off-site ranges located at the White Sands Missile Range, New Mexico; Poker Flats Research Range, Alaska; and the National Scientific Balloon Facility, at Palestine, Texas. Mobile campaigns for balloon and sounding rocket launches are conducted at various sites throughout the world.

The ranges at Moffett Field, Crows Landing and the Dryden Flight Research Facility (DFRF) are under the management of Ames Research Center (ARC) and are configured to support aeronautics research. The DFRF has the additional capability to support Shuttle landings.

The AB&SR system implementation program is directed primarily at the systematic replacement of obsolete systems and the upgrade of these facilities to assure reliable support to NASA's research programs.

Support to the aeronautical research efforts and scientific experiments using sounding rockets and balloons requires fixed and mobile instrumentation systems which include radar, telemetry, optical, communications, command, data handling and processing systems. To maintain these facilities, replacement parts must be acquired, test and calibration equipment routinely replaced, and equipment refurbished or modified to assure reliable support. The FY 1990 funding estimate also includes system, supply and support services procurements deferred to FY 1990 that could not be accommodated within the FY 1989 reduced funding levels.

Aeronautics, balloons, and sounding rocket (AB&SR) support operations

The operations element of the AB&R program includes the operations and maintenance of ground-based instrumentation systems,

both fixed and mobile, under the management of the Ames Research Center (ARC) and the Goddard Space Flight Center (GSFC). These facilities support NASA aeronautics, sub-orbital, and a limited number of Earth orbit research programs. Funding provides for services and consumable supplies required to operate and maintain the radar, telemetry, data acquisition, data processing, data display, communications and special purpose optical equipment essential to the conduct of these research programs.

The aeronautical test ranges at the Dryden Flight Research Facility (DFRF) and the Moffett Field Flight Complex (MFFC), under the auspices of the Ames Research Center, maintain an active schedule of aeronautics research support. During FY 1988, more than 1625 missions were conducted at DFRF and MFFC. In FY 1989, approximately 1700 aeronautical missions will be supported at these locations. Programs supported by the ranges encompassed a wide variety of activities including revolutionary aircraft configurations, advanced technologies high performance aircraft, highly integrated control systems and powered lift technologies.

The GSFC activities support aeronautics programs as well as sounding rocket, balloon and Earth orbiting satellite programs at the Wallops Flight Facility (WFF). During 1988, approximately 220 aeronautics missions were supported at the WFF covering such programs as heavy payload mid-air retrieval systems development, XV-15 Aircraft Noise Program, runway friction testing, microwave landing system operations testing, storm hazards research, and the general aviation light aircraft thruster research program. In 1989, approximately 220 aeronautical missions will be supported by WFF.

The sounding rockets program at the WFF conducted approximately 33 launches in FY 1988 of rockets with major scientific payloads. In FY 1990, approximately 40 such launches will be supported. In addition, WFF launched a number of the smaller meteorological and special purpose rockets supporting a variety of research programs. In support of the NASA scientific balloon program, WFF launched 46 larger balloons in FY 1988 with major scientific payloads. In FY 1989, approximately 55 large balloon launches will be supported. Earth orbiting satellites supported included International Ultraviolet Explorer, Interplanetary Monitoring Platform-8, and Nimbus-7, Dynamics Explorer-1, Meteosat, and landsat.

The funding estimate for FY 1990 is based on a level of activity about 10 percent higher than the FY 1989 level of effort but also includes maintenance and support services deferred to FY 1990 that could not be accommodated within the FY 1989 reduced funding level. The specific adjustments included deferred maintenance on the FPS-16 and EPQ-6 radars, control center engineering support, and logistics support. The funding for AB&R program operations includes support services contractor operations and maintenance personnel, logistical support, and technical services for the ground-based fixed and mobile instrumentation systems supporting the ongoing sounding rocket, balloon, Earth orbiting satellite and aeronautical research programs.

COMMUNICATIONS AND DATA SYSTEMS

	1989 current estimate	1990 budget request
Communications systems implementation	\$10,400,000	\$12,500,000
Communications operations	108,400,000	115,500,000
Mission facilities.....	8,800,000	7,800,000
Mission operations	31,200,000	38,700,000
Data processing systems implementation.....	25,500,000	20,900,000
Data processing operations.....	49,000,000	54,800,000
Total	233,300,000	250,200,000

Funds requested for the Communications and Data Systems program provide for the implementation and operation of facilities and systems which are required for data transmission, mission control and data processing support.

Communication circuits and services provide for the transmission of data between and among the remote tracking and data acquisition facilities, the TDRSS Ground Terminal, launch areas, and the mission control centers. Real-time information is crucial to determine the condition of the spacecraft and payloads for the generation of spacecraft and payload control commands. Data received from the various spacecraft must be processed into a usable form for spacecraft monitoring in the control centers and before the transfer of data to the experimenters. Missions supported include Shuttle, Spacelab, NASA scientific and application projects, and international cooperative efforts.

Major activities underway include: implementing necessary changes and completion of testing of the Hubble Space Telescope mission control and data capture system, and missions control and data processing capabilities required to support upcoming mission such as Gamma Ray Observatory (GRO), Spacelabs, Upper Atmosphere Research Satellite (UARS), Global Geospace Science (GGS), Collaborative Solar Terrestrial Research (COSTR), Cosmic Background Explorer (COBE), and Advanced X-ray Astrophysics Facility (AXAF). In addition, studies are continuing to evaluate Space support requirements.

Communications systems implementation

The objective of the Communications Systems Implementation program is to provide the necessary capability in NASA's Global Communications Network (NASCOM) to meet new program support requirements, to increase the efficiency of the network, and to keep NASCOM at a high level of reliability for the transmission of data. NASCOM interconnects the tracking and data acquisition facilities which support all flight projects and also links such facilities as launch areas, test sites, and mission control centers.

The major effort being initiated in NASCOM is planning, engineering, and equipment acquisition required to tie together the existing TDRSS ground terminal at White Sands, New Mexico, with the Second TDRSS Ground Terminal (STGT). This requires an integrated communications for the control and transfer of data between the two facilities. The secondary effort under way is the equipment acquisition to upgrade the Deep Space Network's

ground communications data handling capability at Madrid, Spain; Tidbinbilla, Australia; and the Jet Propulsion Laboratory.

The FY 1990 funding requirements will provide the sustaining equipment and modifications to support the NASCOM network and provide for the continued engineering and equipment acquisition to support the STGT at White Sands. New peripherals will be purchased to replace the outmoded models presently in use for the message switching system (MSS). Funding will also provide for the increased ground communications data handling capability required in the Deep Space Network to support the combined data rates of the Magellan, Galileo, and Ulysses satellites.

Communications operations

OBJECTIVES AND STATUS

NASA's global Communications Network (NASCOM) interconnects, by means of leased voice, data, and wideband circuits, the tracking and data acquisition facilities which support all flight projects. Also, NASCOM links such facilities as launch areas, test sites, and mission control centers. Goddard Space Flight Center (GSFC) operates the NASCOM and serves as its major switching control point. In the interest of economy, reliability, and full utilization of trunk circuitry, subswitching centers have been established at JPL and Madrid. The NASA flight projects require the transfer of data between the mission control centers and the sites because of the need for real time control of spacecraft and on-board experiments.

NASA's Program Support Communications Network (PSCN) interconnects the NASA Centers, Headquarters, and major contractor locations through leased voice, data and wide-band circuits for the transfer of programmatic and scientific information. Marshall Space Flight Center (MSFC) operates the PSCN and serves as its major switching control point.

The FY 1990 funding requirements for the NASCOM Communications Operations program will provide the circuit and service required to operate and maintain the NASA Global Communications Network. International communications satellites and cables will continue to provide digital wideband services to all the overseas tracking stations. Domestic satellite systems and terrestrial networks will continue to service the continental United States stations. With the reactivation of the Shuttle communications network and the trend toward fiber optic systems, there will be a dramatic increase in the use of digital technology in NASCOM with a corresponding decrease in the use of analog technology. Funding is also required to simultaneously support the Shuttle and the deep space projects with wideband data links to the Deep Space Network stations in Spain and Australia.

Funds are included for Program Support Communications Network (PSCN) which provide for the circuits and facilities for, programmatic operations such as data transmission and computer-to-computer data sharing for NASA Centers and Headquarters. In FY 1990, funds are required to operate and maintain the PSCN hardware and wideband satellite and terrestrial circuits at all NASA locations and selected contractor sites. The network will support all

NASA programs and projects such as the Shuttle, Hubble Space Telescope, and Space Station Freedom.

Mission facilities

The Mission Facilities Implementation program provides the capabilities needed for the command and control of NASA's unmanned scientific and applications satellite programs. Command and control of the spacecraft and on-board experiments are carried out via the Payload Operations Control Centers (POCC's) and related mission support systems.

The POCC's are responsible for the receipt, processing, and display of spacecraft engineering data and transmission of commands. Four POCC's currently monitor and control numerous spacecraft. In addition, a new dedicated control center is nearing completion for control of the Hubble Space Telescope scheduled for launch in the first quarter of FY 1990. Related mission support systems include a Johnson Space Center/Goddard Space Flight Center Shuttle POCC Interface Facility (SPIF) and a Mission Planning/Command Management System to schedule spacecraft support and generate command sequences for transmission to the spacecraft by the POCC's.

The FY 1990 funding requirements will provide for completion of Hubble Space Telescope prelaunch systems testing and for continuing software development. This software will make the operation of the spacecraft more efficient resulting in increased science return, and will provide modifications determined to be required during the final ground testing and early orbit phases of the mission.

Also in FY 1990, funds are included for modifications to the existing Multi-satellite Operations Control Center (MSOCC) for control of the Gamma Ray Observatory (GRO), Upper Atmosphere Research Satellite (UARS), Extreme Ultra-Violet Explorer (EUVE), GGS, COSTR, and various Shuttle attached payload. In addition to the new spacecraft support capabilities being provided, the outmoded MSOCC switches, which route data throughout the control center and to and from external sources, will be replaced in FY 1990.

Mission operations

The Mission Operations program in FY 1990 will provide for the operation of the five Payload Operations Control Centers (POCC's) and the related software and support services necessary for the monitoring and control of eight in-orbit spacecraft and prelaunch preparations for five new spacecraft.

The POCC's, which are the control facilities for spacecraft/payload operations, have the capability for receiving, processing, and displaying spacecraft engineering and telemetry data and for sending commands to the spacecraft. Commands transmitted to the spacecraft include both emergency and commands resulting from decisions made by the spacecraft analysts and preplanned command sequences generated in advance to carry out the mission objectives. Each POCC is operated 24 hours per day, 7 days per week in mission support. For Shuttle missions with attached payloads operated by GSFC, there is a specialized GSFC Shuttle Payload Inter-

face Facility (SPIF) which processes and provides for the display of Shuttle-unique data that is necessary for payload control.

The FY 1990 budget request includes funds to operate the POCC's and supporting facilities for control of on-orbit missions and to develop control center software to support uncoming missions. In early FY 1990, the new Hubble Space Telescope (HST) will be launched, followed by an intense period of on-orbit checkout of this new observatory. FY 1990 funds will provide the first full year of around the clock, seven days per week operation in the HST control center to support the preparations for launch, perform the operational checkout and calibration of the spacecraft, its scientific instruments, and for the operation of the observatory to obtain scientific data. Also in FY 1990, software development activities will continue for the GRO and UARS missions, and the software development activities will increase for the EUVE, GGS, COSTR, and AXAF spacecraft to meet the planned launch dates.

Data processing systems implementation

The Data Processing Systems Implementation program provides for the procurement of equipment and related services for the large data processing and computation systems at the Goddard Space Flight Center (GSFC). These systems support both the operational and payload requirements of flight missions. To meet operational requirements, these systems determine spacecraft attitude and orbit and generate on-board commands to the spacecraft subsystems. In support of spacecraft payloads, the systems process the data for science and applications experiments for subsequent transfer to the experimenters for analysis.

Major computation capabilities include the Flight Dynamics Facility which performs the real-time attitude, orbit computation and flight maneuver control functions and the Mission Operations and Data Systems Information Network (MODSIN). Also included is the improvement in the test bed facility to be used for prototyping, testing, and evaluating maturing technologies resulting from the Advanced System Program. Promising technologies for application to future support will be investigated in the areas of remote payload operation and control, expert systems, high speed data processing, high level languages, and very large scale integration (VLSI). In addition, there are four major systems for processing payload data: 1) the Telemetry On-Line Processing System (TELOPS) which routinely supports a number of Earth-orbiting spacecraft; 2) the Image Processing Facility (IPF) which can support satellite imaging requirements; 3) the Spacelab Data Processing Facility (SLDPF) which has provided support to the Spacelab missions and the Shuttle Imaging Radar-B experiment; and 4) the Hubble Space Telescope Data Capture Facility (HSTDCF) which will capture, process, and forward to the Science Institute Facility the packetized telemetry data from the Hubble Space Telescope spacecraft. Significant activities in this program continue at GSFC to keep the large systems viable and responsive to project support requirements. Implementation continues on new systems to process data from the Gamma Ray Observatory (GRO) and the Upper Atmosphere Research Satellite (UARS) missions.

Multiple contractors will be chosen for definition studies and preliminary design for the Customer Data and Operations Systems (CDOS) in FY 1989. These studies will be for new institutional communications and data systems capabilities required to support the Space Station Freedom Program and other payloads in the Space Station era.

The FY 1990 budget request will provide continued funding for improvements in the existing computation systems at GSFC which provide real-time support to NASA spacecraft. Funding is also included for continuation of development of the MODSIN Host system and initial development of a generic application software for combined operational mission planning and attitude support system. In addition, the request provides for the improvement and upgrade of the Flight Dynamics Facility (FDF) and for systems studies in autonomous navigation.

The FY 1990 budget request also includes funds to continue the upgrade of the existing TELOPS system in order to develop a generic time division multiplexed (TDM) system for processing data. The Upper Atmosphere Research Satellite (UARS), will be the first user. The handling of UARS data will serve as a demonstration for providing such support to other users and allow trade-off analyses between development costs and support risks for future missions. Funds are also requested for upgrading the data processing capabilities at GSFC to facilitate the exchange of data within the data processing complex and with other mission support facilities.

Requested funding provides for the procurement and maintenance of an adequate supply of unique spare parts to replace failure-prone and high-maintenance electronic modules, to provide test equipment, and to undertake minor modifications and hardware fabrication associated with new equipment installation and reconfiguration.

Funds are included in the request for continuing the evaluation of Space Station support requirements and the capabilities needed to meet those requirements. The systems definition study will be completed for the Customer Data and Operations Systems (CDOS) which will provide a preliminary design and specifications leading to a projected system readiness date of July 1995.

Data processing operations

Information received in the form of tracking and telemetry data from the various spacecraft must be processed into a usable form before transfer to the experimenters. This transformation and computation process is performed as part of the data processing function and applies to a wide variety of programs, ranging from the small Explorer satellites to more complex imaging satellites.

In addition to the actual processing of data, upcoming projects require extensive prelaunch orbit analysis. Spacecraft position and attitude predictions analyses are also required to develop operational sequences and procedures. Benefits from these studies include optimization of systems resources such as, look angles for maximum science data return during the actual spacecraft operation. Similar efforts will focus on flight dynamics support for the COBE launch in FY 1989.

Telemetry data is the primary product of spacecraft, and it is through reduction and analysis of this data by the experimenters that the mission objectives are achieved. Data are processed to separate the information obtained from various scientific experiments aboard the spacecraft, to consolidate information for each experimenter, to determine spacecraft attitude, and to correlate these measurements with time and spacecraft position data. Four facilities, the Image Processing Facility (IPF), the Telemetry On-Line Processing System (TELOPS) facility, the Spacelab Data Processing Facility (SLDPF), and the Hubble Space Telescope Data Capture Facility (HSTDCF) have been established at the Goddard Space Flight Center to preprocess different types of raw experiment data. Sustained operations of these facilities is needed to support the ongoing spacecraft in-orbit.

The IPF, initially established to handle image data from the Landsat-1 satellite, has supported many missions over the ensuing years. The TELOPS handles satellite non-image data which is received in a digital form from the tracking stations via NASCOM. It is capable of electronically storing large volumes of telemetry data, thus eliminating most of the tape and tape handling operations. Facility management, maintenance and operations, and software development support for the image and non-image data processing facilities are also provided. The operation of the SLDPF is included along with software development and maintenance required for attitude determination, flight maneuvers, mission simulations, and the Mission Operations and Data Systems Information Network (MODSIN).

The FY 1990 budget request provides for operation of the various computation and data processing facilities including the SLDPF which provides unique hardware and software support to Spacelab and Dedicated Discipline Laboratory (DDL) missions. Pre-mission, mission and post-mission support for FY 1990 launch of Astro-1/BBXRT, Starlab, Atlas-1, and SLS-1 millions is required. In addition, preparation for future missions such as TSS-1, Wamdi, SL-J, and Astro-2, will be continued. Support for ongoing spacecraft, such as, SMM, IUE, ICE, ERBS, DE, and COBE consists of software enhancements and maintenance on a continuing basis in order to perform flight control and maneuver operations and for the data processing activities. Funding is required to support the Space Station Platform Flight Dynamics analysis and CDOS software support environment (SSE) buildup.

Application software development, prototyping, and system testing are continuing for upcoming science and applications missions such as AXAF, GGS, COSTR, GRO, ASP, UARS, and EUVE. Funding is also required for the Solar Heliospheric Observatory (SOHO) element of COSTR.



CONSTRUCTION OF FACILITIES

GENERAL STATEMENT

The Construction of Facilities (CoF) appropriation provides contractual services for the repair, rehabilitation and modification of existing facilities; the construction of new facilities and the acquisition of related facility equipment; environmental compliance activities; the design of facilities projects; and advance planning related to future facilities needs.

The funds requested for FY 1990 provide for continuing prior year endeavors to meet facilities requirements for the space technology and aeronautical research; continuation of the multi-year effort to restore and modernize NASA's aeronautical research and development facilities; repair, rehabilitation and modification of other facilities to maintain, upgrade and improve the usefulness of the NASA physical plant; minor construction of new facilities, facility planning and design activities, and environmental compliance and restoration.

The projects and amounts in the budget estimates reflect Space Station Freedom and Space Flight requirements that are time-sensitive to meet specific program objectives. Other program requirements for 1990 include refurbishing bridges, Merritt Island, and rehabilitation of the Spacecraft Assembly and Encapsulation Facility II at the Kennedy Space Center, rehabilitation of the central heating/cooling plant at the Johnson Space Center, construction of a Data Operations Facility and a Quality Assurance and Detector Development Laboratory at the Goddard Space Flight Center, modernization of the south utility systems at the Jet Propulsion Laboratory, projects to repair, restore, and modernize NASA's aeronautical research and development facilities at Ames, Lewis, and Langley Research Centers, and at the Plum Brook Station, construction of an Automation Sciences Research Facility at the Ames Research Center, construction of a Supersonic/Hypersonic Low Disturbance Tunnel at the Langley Research Center, and modifications for seismic safety, Goldstone, California.

The FY 1990 program continues to meet the objectives of preserving and enhancing the capabilities and usefulness of existing facilities and ensuring safe, economical and efficient use of the NASA physical plant. This request continues the necessary rehabilitation and modification program begun in prior years and continues a repair program. The repair program restores facilities to a condition substantially equivalent to their originally designed capability. The minor construction program continues to provide a means to accomplish smaller facility projects which accommodate changes in technical and institutional requirements. The environmental compliance and restoration program ensures that statutory

environmental requirements are met and any necessary remedial action promptly taken.

Funds requested for facility planning and design cover planning and design requirements for potential future projects, master planning, facilities studies, engineering reports and studies and the preparation of facility project design drawings and bid specifications.

The FY 1989 CoF Program includes \$15,000,000 transferred from DOD to NSAS for initiation of design and construction of a component and subsystem test facility at the Stennis Space Center to support the Advanced Launch System.

The budget authority requested for FY 1990 is \$341,800,000, with estimated outlays of \$237,118,000.

In addition to the above, four projects are proposed for private sector financing and are described in the addendum to this budget submission. These projects are the Advanced Solid Rocket Motor production and test facility, Yellow Creek, Mississippi, the Space Station Processing Facility at the Kennedy Space Center, the Neutral Buoyancy Laboratory at the Johnson Space Center, and the Observational Laboratory at the Jet Propulsion Laboratory. The projects selected for privatization are functionally suitable for processing, developing, or manufacturing commercial space products as well as directly supporting NASA programs. Economic analyses show that privatization is cost beneficial to the Government, provided the proposer retains 20 percent or more ownership of the facilities. It also precludes large outlays by the Government in FY 1990 and FY 1991.

<i>Item</i>	<i>Amount requested</i>
1. Construction of Addition for Space Systems Automated Integration and Assembly Facility (JSC).....	\$10,500,000
2. Construction of Addition to Mission Control Center (JSC).....	17,800,000
3. Construction of Addition to the Simulator/Training Facility (JSC).....	3,800,000
4. Modification for Expanded Solar Simulation (JSC)	2,000,000
5. Modifications of Process Technology Facility for Space Station (Marshall SFC).....	4,000,000
6. Replace Cooling Towers, Launch Complex 39 Utility Annex (KSC).....	1,200,000
7. Replace Launch Complex 39, Pad A Chillers and Controls (KSC) .	4,600,000
8. Replace Roofs, Launch Complex 39 (KSC).....	11,000,000
9. Replace Vehicle Assembly Building Air Handling Units (KSC) ...	1,800,000
10. Upgrade Orbiter Modification and Refurbishment Facility to Orbiter Processing Facility No. 3 (KSC).....	26,000,000
11. Modification of High Pressure Industrial Water System (Stennis SC)	2,000,000
12. Replacement of High Pressure Gas Storage Vessels (Stennis SC)	3,000,000
13. Construction of National Resource Protection (various installations).....	3,800,000
14. Refurbish Bridges, Merrit Island (KSC).....	4,500,000
15. Rehabilitation of Spacecraft Assembly and Encapsulation Facility II (KSC).....	3,500,000
16. Rehabilitation of Central Heating/Cooling Plant (24) (JSC).....	2,800,000
17. Construction of Data Operations Facility (Goddard).....	12,000,000
18. Construction of Quality Assurance and Detector Development Laboratory (Goddard).....	7,500,000
19. Modernization of South Utility Systems (JPL).....	5,400,000
20. Construction of 40x80 ft. Wind Tunnel Drive Motor Roof (Ames)	1,000,000
21. Modifications to Thermo-Physics Facilities (Ames).....	4,600,000
22. Modifications to 14x22 Subsonic Wind Tunnel (1212C) (Langley).	1,900,000

<i>Item</i>	<i>Amount requested</i>
23. Modifications to National Transonic Facility for Productivity (1236) (Langley).....	2,400,000
24. Modifications to 20 foot Vertical Spin Tunnel (645) (Langley).....	7,600,000
25. Rehabilitation of Central Air Systems (Langley).....	2,400,000
26. Rehabilitation of Central Refrigeration Equipment (Langley).....	7,200,000
27. Rehabilitation of 8x6 Supersonic and 9x15 Low-Speed Wind Tunnels (Lewis).....	6,800,000
28. Rehabilitation of Hypersonic Tunnel, Plum Brook Station (PBS) (Lewis).....	4,100,000
29. Repair and Modernization of the 12-foot Pressure Wind Tunnel (Ames).....	27,600,000
30. Construction of Automation Sciences Research Facility (Ames)...	10,600,000
31. Construction of Supersonic/Hypersonic Low-Disturbance Tunnel (1247D) (Langley).....	6,900,000
32. Modifications for Seismic Safety, Goldston, CA. (JPL).....	2,600,000
33. Repairs of Facilities, Not in Excess of \$750,000 Per Project (various facilities).....	28,000,000
34. Rehabilitation and Modification of Facilities, Not in Excess of \$750,000 Per Project (various facilities).....	36,000,000
35. Minor Construction of New Facilities and Additions to Existing Facilities, Not in Excess of \$500,000 Per Project (various facilities).....	10,000,000
36. Facility Planning and Design (various locations).....	26,300,000
37. Environmental Compliance and Restoration Program (various locations).....	30,000,000

CONSTRUCTION OF ADDITION FOR SPACE SYSTEMS AUTOMATED INTEGRATION AND ASSEMBLY FACILITY, LYNDON B. JOHNSON SPACE CENTER

This project will provide an area for high-fidelity dynamics simulation testing of manual and automated construction techniques and hardware, component attachment methods, and verification/inspection techniques for on-orbit Space Station structural assembly tasks and similar applications. The high-bay addition will accommodate several six-degree-of-freedom simulators, a 40-foot by 40-foot air-bearing floor, and static test area for various Space Station structures, components and test fixtures. The three-story laboratory support addition is required for associated technician work and staging, test and applications computing support, techniques development laboratories, transient engineering support space and mechanical equipment. As an addition to the integration and mockup area supporting Space Shuttle and Space Station, the new area will benefit from shared accessibility, experience, techniques, support personnel, and special facilities. Enlargement of the existing air-bearing floor is required to accommodate full-scale dynamics tests utilizing the Shuttle and Space Station remote manipulator system already established/planned for this location. Accomplishment of Johnson Space Center (JSC) responsibilities for engineering and integrated ground verification prior to flight requires the capabilities provided by this project. This building addition is the most cost-effective means for meeting these requirements. These capabilities must be provided to verify on-orbit assembly methods and procedures.

This project provides for construction of an addition to the east end of the Systems Integration and Mockup Laboratory of Building 9 consisting of approximately 47,000 sq. ft. The addition includes a 21,000-sq.-ft. high-bay area and a 26,000-sq.-ft. three-story laboratory support area. The project also provides for increasing the exist-

ing air-bearing surface area in the Systems Integration and Mockup Laboratory by 3,000 sq. ft. and providing 1,600 sq. ft. of air-bearing surface in the new high-bay area. Additionally, the project includes extending the existing high-bay bridge crane; installing an elevator in the laboratory support area; connecting to the JSC utility tunnel systems, electrical power, and air-conditioning. A paved parking lot for approximately 60 vehicles will be provided to support building personnel and replace parking spaces lost by construction of the addition.

CONSTRUCTION OF ADDITION TO MISSION CONTROL CENTER, LYNDON B. JOHNSON SPACE CENTER

This project is required to provide space for the initial and continuing basic ground support of the Space Station orbital assembly. Beginning with the first element launch, the facility will be required for support of real-time, near-real-time, and follow-on operations management, engineering analyses, contingency planning/operations and logistics coordination/management for the life of the Space Station program. The facility must be fully operational prior to the first element launch with sufficient time provided for systems installation, activation, testing and verification of procedures.

The Space Station Control Center (SSCC) is required for Space Station operations. Proximity with the existing MCC is required for sharing of common skills, personnel, equipment, communications and data. Engineering and maintenance tasks will be shared with Space Transportation System (STS) programs. The MCC will remain configured for and dedicated to STS operations planned through the 1990's. Limited sharing of MCC areas will be possible, however, the STS mission support rate, manpower, equipment severe requirements in the MCC make it unsuitable and unavailable for use as the SSCC.

This addition provides the needed operations and associated equipment areas required for the continuous support of the Space Station. Operations management, support, planning, evaluation and simulation areas are included. It is anticipated that up to 55 civil service and 190 contractor personnel on a prime shift will be in the facility during Space Station operations; and two and one-half times this number is anticipated during anomalies and emergency operations. The facility will be used 24 hours a day. It is therefore essential that this facility be constructed.

This project provides for construction of a five-story addition with a second-floor mezzanine at the southwest corner of the existing MCC, Building 30, MOW. The addition will consist of approximately 106,000 square feet for Space Station operations support and data processing/storage. Included in this project will be air-conditioning and heating; fire detection, alarm, and suppression systems; electrical power; and lighting as required for the various areas. Also included will be raised flooring and air-conditioning required by the computer equipment. Various existing underground utilities will be relocated and new storm drainage, sanitary sewer and water lines will be connected to existing-site systems to serve the new addition. Areas will also be provided for visitor access and viewing, rest rooms, corridors, stairways, elevators and mechani-

cal/electrical room facilities. An existing paved service drive, located on the west side of the MOW, will be reconfigured for access to the addition. A loading dock, pedestrian walkways and a paved parking area also will be provided.

CONSTRUCTION OF ADDITION TO THE SIMULATOR/TRAINING FACILITY, LYNDON B. JOHNSON SPACE CENTER

This project provides necessary facility space to accommodate the trainers needed for Space Station-unique systems, operations, and crew stations. Space Station flight crews and ground-controllers require numerous trainers for multiple part-tasks and single-system tasks, and abbreviated crew-station activities. Trainers must cover a wide range of physical, mechanical and computer-aided systems of low- and high-fidelity. These systems must be fully integrated for ground/flight coordination and capable of individual or multiple-person use. These Space Station-unique trainers and ancillary support cannot be accommodated in the existing Shuttle Mission Simulators (SMS) complex.

The scope of this project makes maximum use of existing Building 5 facilities and adds only the minimum space necessary to accommodate the Space Station simulation and training. Use of 9,500 sq. ft. of existing floorspace represents a significant saving in cost. This existing space and the ground floor of the addition is required for location of the various trainers. The upper-floor of the addition is required for electronic equipment, maintenance, operations, parts storage, work areas and miscellaneous facility support space.

This project provides for the construction of a three-story building addition and modifications to Building 5. The addition to the south side of the existing south-wing high bay includes 23,000 sq. ft. of floor space. The first floor of the addition will comprise approximately 7,400 sq. ft. with 4,300 sq. ft. of computer flooring. The second floor of the addition will contain approximately 7,400 sq. ft. with 6,900 sq. ft. of computer flooring. The third floor will be a future computer room of approximately 7,400 sq. ft. The existing high bay will be modified by the removal of existing walls, the addition of approximately 3,000 sq. ft. of computer flooring, and approximately 1,000 sq. ft. of rest room space. The project work also includes heating, ventilation and air-conditioning; and elevator, stairs and mechanical room. Site work includes utilities to the addition, modification of storm drainage, landscaping and the construction of a paved parking area for approximately 170 vehicles. A secure wall with a security entrance will be provided between the existing high bay and the existing secure area of Building 5.

MODIFICATION FOR EXPANDED SOLAR SIMULATION, LYNDON B. JOHNSON SPACE CENTER

This project is required to provide high-fidelity solar simulation test environments for the large, complex, and thermally sensitive space structures of the Space Station program. Testing requirements for both Chambers A and B are increasing in quantity and simulation capability for critical Space Station and STS hardware systems. In-house and contractor technology development testing needs for Space Station thermal test beds are immediate. However, partial and integrated structures testing will be required in these

chambers. The expansion of the solar simulation capability provided by this project will assure the availability and quality of space environment testing for a variety of technology demonstrations and/or assessments and for actual flight hardware testing and verification. A high-quality solar simulation component of space-environment testing is required to assure the adequacy of structural and system designs while minimizing the hardware and mission performance costs of artificially "safe" overdesigns. The solar simulation capability provided by this project re-establishes that capability. This capability was vital to the successes of earlier program space systems tested in these unique man-rated chambers. Space Station operations and success requirements mirror those of the Apollo program where vehicles and systems had to perform properly.

This modification of the Space Environment Simulation Laboratory (SESL), Building 32, provides for the upgrading and expansion of facilities for solar simulation systems. The modification of the facilities for Chamber B will enable the number of solar xenon lamps to be increased from 19 to 37, thereby enlarging the diameter capable of being irradiated in the chamber from 13 to 20 feet. In addition, Chamber A will be retrofitted and reconfigured to accept up to 37 xenon light modules in 63 positions. The project includes replacing the existing heat exchanger in Chamber B with a unit of sufficient capacity to handle the additional heat produced by the new light modules. The existing Chamber B cooling system will be extended to Chamber A by interconnecting piping. A new de-ionized water pump, valves and flow controls will be installed to support full xenon light module operation. Stainless steel water piping assemblies will be installed beneath new, raised computer flooring in Chambers A and B for the light power supply units. As part of the Chamber A reconfiguration, the obsolete carbon arc power, control and gas and water piping assemblies will be replaced with cabling and gaseous nitrogen piping. These upgrades are required to support the xenon light modules. The guide rail extensions on Chamber A will be removed and the elevator platform will be extended. Eleven Chamber A wall nozzle penetration assemblies will be modified to correct anomalies in alignment to accommodate module installation.

MODIFICATIONS OF PROCESS TECHNOLOGY FACILITY FOR SPACE STATION, GEORGE C. MARSHALL SPACE FLIGHT CENTER

The manned space station is being developed to remain in orbit for approximately 20 years. In order to provide longevity and successful operation, structural repair and refurbishment of sealants and surface coatings must be accomplished in orbit. Development of the required special repair equipment must include testing in a simulated vacuum environment. Robotized electron beam welding, cutting, soldering and metal spray coating will be developed and demonstrated. Means of managing the debris generated by this process will be studied. Repair equipment must be optimized for efficiency, reliability and compactness. The Space Station has twice the volume of Skylab and more than 1,000 linear feet of seals. Accordingly, initial priority will be placed on verification of seal concepts and leak rate. Outgassing characteristics will be determined.

Also needed is the development of an on-orbit bonding and sealing technique, and adhesives and coatings for Space Station module repair and refurbishment work. Candidate materials must be tested for outgassing, flammability, toxicity, bonding strength and sealing efficiency. A laser will be used for the development of ground operations and on-orbit applications including welding and cutting. Work will also include precision alignment of large structures, non-destructive testing and leak detection. The water knife laboratory will provide the capability for development of ground manufacturing processes with computerized robotic high-pressure water jet cutting of high strength metals and advanced composites to reduce the weight of space structures and launch vehicles.

Work includes the modification of approximately 4,000 square feet (sq. ft.) of space with the installation of a 10-foot by 15-foot-working diameter Space Environment Vacuum Chamber (Figure 2), a clean room area of 1,500 sq. ft., control room, and instrumentation. This includes the modification of 2,150 sq. ft. of space for cryo pumps and related mechanical equipment. The thermal shrouds in the vacuum chamber and cryo pumps will be cooled with liquid nitrogen (LN₂) supplied from a 13,500 gallon Government Furnished Equipment (GFE) LN₂ dewar. Work also includes an addition to the building of 1,460 sq. ft. of steel frame and roof construction for a robotic water jet laboratory and modification of 1,330 sq. ft. for a composite test component preparation cell.

REPLACE COOLING TOWERS, LAUNCH COMPLEX 39 UTILITY ANNEX, JOHN F. KENNEDY SPACE CENTER

This project is required to provide the necessary cooling for Shuttle processing activities at Launch Complex 39 (Figure 2). The facilities supported include the Vehicle Assembly Building, Launch Control Center, Orbiter Processing Facility, Orbiter Modification and Refurbishment Facility and Thermal Protection System Facility.

The two existing 5,000-ton wooden towers are in a severely deteriorated condition, and recent temporary repairs and continued maintenance cannot keep the towers operational much longer. The growth in cooling requirements now exceeds the capacity of one 5,000-ton tower, and both towers cannot be maintained in continuous operation. A new cooling system with additional capacity is needed to restore reliability of air-conditioning support to STS operations. The proposed four-cell cooling tower (Figure 3) will accomplish this requirements by providing the capability to have two cells on-line, one held in backup to satisfy STS launch requirements, and one cell taken off-line for maintenance or repair.

The project provides for the removal of the existing wooden cooling towers and associated equipment and replacement with a masonry/ceramic four-cell tower. Condenser water pumps and associated piping will be replaced. A new motor control center and power distribution system will be installed. New condenser water supply and return mains will be provided between the new tower and the Launch Complex 39 Utility Annex.

REPLACE LAUNCH COMPLEX 39, PAD A CHILLERS AND CONTROLS, JOHN F. KENNEDY SPACE CENTER

The existing chillers at Pad A exceed 21 years of age and have reached the end of their service life. These chillers provide chilled water for the environmental control of various launch pad facilities including the Pad Terminal Connection Room (PTCR), Mobile Launcher Platform (MLP), Payload Changeout Room (PCR), Environmental Control System (ECS) Room, Rotational Service Structure (RSS) and Fixed Service Structure (FSS). Failure of these chillers to generate a sufficient quantity of chilled water could result in a Shuttle launch delay. The cooling load during count-down now exceeds the capacity of two chillers, requiring all three chillers to be on-line to support a launch. This operating condition does not provide the needed redundancy of having to have one chiller available for back-up, and greatly increases the risk of interrupting a launch countdown.

This project replaces three existing 225-ton chillers with three new 300-ton chillers. One new chiller will be located in the remote chiller plant (J8-1707) and two new chillers will be located in Room 107 within the PTCR area (Figure 2). Electrical power, new chilled water pumps, controls and an additional cooling tower cell will also be installed.

REPLACE ROOFS, LAUNCH COMPLEX 39, JOHN F. KENNEDY SPACE CENTER

The flat roofs of the VAB and LCC do not drain adequately (Figure 2). Following heavy rains, as much as four inches of water may be standing on large areas of the roofs. When this occurs, defects in the roof's 23-year-old water proofing membrane permits water penetration to fully saturate the roof insulation and intrude into fissures in the supporting concrete structural decks. This intrusion has caused some corrosion of reinforcement steel and spalling of concrete which, as it falls, threatens damage to flight hardware and support equipment in the VAB. Roof drainage capability must be improved in both the VAB and LCC to eliminate the effects of standing water. The VAB and LCC are among the most critical and valuable facilities at KSC. It is essential to the success of the Shuttle Program that their roofs be restored to a water tight condition to protect the buildings and their contents.

This project provides for the removal of approximately 324,200 square feet of existing roofing system down to the concrete deck. The existing decks will be repaired, as required, and a new tapered (for rapid drainage) roofing base and additional drains will be installed. Within the 525-foot-high VAB, additional drain pipes (leaders) will be installed from the roof down to ground level to accelerate storm water removal. A new roofing membrane and insulation will be installed with the inclusion of adequate expansion joints.

REPLACE VEHICLE ASSEMBLY BUILDING AIR HANDLING UNITS, JOHN F. KENNEDY SPACE CENTER

The present air handling units are no longer economical to operate, are not reliable, and the cost of maintenance is very high for both manhours and materials. Many spare parts are no longer available. These units will be over 25 years old by the time they

are replaced and will have exceeded their normal operation life expectancy. The installation of more efficient units will reduce energy consumption and maintenance costs. Equipment will have a higher level of environmental protection, and performance of equipment and personnel will be improved by optimum temperature/humidity conditions.

This project consists of replacing or refurbishing 23 air handling units (Figure 2), associated piping, and electrical power and controls in the following towers of the VAB high bay and areas in the low bay: (Tower or Area Designation—Number of Air Handlers), A-1, B-4, C-2, D-2, E-5, F-3, K-2, L-1, M-2, and N-1.

UPGRADE ORBITER MODIFICATION AND REFURBISHMENT FACILITY TO ORBITER PROCESSING FACILITY NO. 3

Upon returning from a space mission, an orbiter must undergo safing, deservicing, maintenance and checkout before it can be readied for reuse. The significant Orbiter Processing Facility (OPF) operations include draining and purging all fuel systems, removing ordnance and all other hazardous elements, removing payloads brought back from space, inspecting the payload bay and crew cabin, repairing and replacing damaged components and refurbishing the thermal protection system. The hypergolic modules are also serviced. After these operations are completed, the orbiter is prepared for the next flight, the mission payloads are inserted into the payload bay and then moved to the Vehicle Assembly Building (VAB) for stacking operations.

Prior to the 51-L accident, the two existing bays of the OPF and the ORMF were sufficient to accomplish the above. However, post 51-L test and checkout requirements have increased OPF processing times for added safety, reducing the annual turnaround per bay capacity. In addition, in 1991, the replacement (fourth) orbiter will be delivered to KSC, requiring extended use of an OPF bay for initial checkout and activation, further complicating processing activities.

To process the orbiters with the increased post 51-L requirements, and to effectively utilize the four orbiter fleet and achieve the anticipated launch rate, a third OPF bay is a mandatory requirement.

This project upgrades the ORMF (Figure 2) to OPF #3 by constructing, modifying and installing an orbiter access system, safing and deservicing capability, and additional 30-ton crane and orbiter processing equipment and support systems. This includes capability for hypergols deservicing, gaseous and liquid hydrogen, gaseous and liquid oxygen, gaseous nitrogen and helium systems, hydraulic and ground coolant piping, electrical, communications, instrumentation and control cabling. These systems will be routed through an under-floor trench system to Orbiter workstations. The project includes construction of a multi-story annex (Figures 3 and 4) enclosing approximately 34,000 gross square feet to provide a central marshalling/locker area for technical and quality control personnel and office space for approximately 175 processing support personnel.

MODIFICATION OF HIGH PRESSURE INDUSTRIAL WATER SYSTEM, JOHN C.
STENNIS SPACE CENTER

Current HPIW reservoir makeup pumping capacity was designed for no more than two firings per quarter. Current Space Shuttle Main Engine (SSME) program operations require a testing frequency of up to 15 static firings per month, substantially increasing makeup water demand. Recent geological studies and surveys indicate that the underground aquifer from which Stennis Space Center (SSC) receives its supply has reduced its flow by approximately 50 percent with the reduction trend continuing from over usage. This aquifer depletion is a problem not limited only to SSC but to the entire Mississippi coastal area. It is becoming a serious concern. To alleviate supply concerns and to mitigate the coastal depletion of water, it is imperative that existing SSC pumping efforts from this aquifer be minimized. This project will provide needed pumping capacity so that water can be drawn from the canal.

A new pump station will be constructed on the main canal south of the existing HPIW reservoir as shown on Figure 1. A portion of the canal will be enlarged to accommodate the pump station and four 5,000 gpm motor driven pumps (three operating and one spare) will be installed on structural steel beams supported by steel piles. Motor starters and monitoring instrumentation will be included for the pump drives with decking and platforms provided for access to the pumps. The side of the enlarged canal will be supported by steel piles. A new header will be installed between the pump station and the existing HPIW reservoir. Electrical power wiring and control signal wiring from the HPIW facility will be provided along with an access road and walkway from the HPIW facility to the new pump station.

REPLACEMENT OF HIGH PRESSURE GAS STORAGE VESSELS, JOHN C.
STENNIS SPACE CENTER

The Stennis Space Center (SSC) Pressure Vessel Recertification Program has identified severe deterioration in several vessels in the "B" Test Complex supporting the SSME Program. Safety standards require that these vessels be derated below the originally designed maximum allowable working pressure or be removed from service. In FY 1989, one 1,500-CF BN_2 storage vessel and one 600-CF gaseous hydrogen (GH_2) storage vessel are being replaced with two 750-CF and one 600-CF high pressure gas storage vessel. This project will complete the replacement and conversion of deteriorated tanks and provide the needed gas storage capabilities to support testing.

The Test Complex Pressure Vessels were fabricated in 1964 and have been in continuous service since that time. These vessels are used for storage of gases up to 6,000 pounds per square inch gauge (psig). The vessels, of laminated construction, are fabricated from High Strength (HS)-1A (T-1) steel. The properties of this steel make it highly susceptible to stress corrosion cracking and requires replacement at this time.

The work includes procurement of two 750-CF GN_2 vessels with a maximum allowable working pressure of up to 6,500 psig; installation of a vessel support structure; modification of interconnecting

piping; and chemical cleaning and testing of the vessels and modified system. The downrated 1,500-CF GN₂ vessel will be converted to high-pressure air to provide better operational efficiency for air drying of the SSME test articles.

CONSTRUCTION OF NATIONAL RESOURCE PROTECTION, VARIOUS INSTALLATIONS

Presidential Decision Memorandum Number 37 (National Space Policy, 1978), Presidential Directive/National Security Council, Number 42 (Civil and Further National Space Policy, 1978), and National Security Decision Directive Number 42 (National Space Policy, July 4, 1982) contain policy designating Space systems and support systems as vital national resources. This designation specifically referenced the Space Transportation System (STS) assets, and required that the survivability of these assets be assured in order to be available for military, scientific, and research uses. STS survivability requires that protective measures be in place at all times to ensure proper, efficient, and effective operation. This project will provide for category "B" resources, which, if lost could result in STS program delay up to 6 months. Funding to protect category "A" resources which, if lost, could cause the loss of an orbiter or crew or would result in a STS program delay greater than 6 months, was provided in the FY 1989 CoF Budget.

Project description.—This project provides for construction of seven-foot-high double chainlink fencing, three-strand barbed wire, concertina wire, automatic gates, vehicle barriers, guardhouses, perimeter lighting, and all electrical work needed to support the lighting, guardhouses, and automatic gates at facilities listed.

At Kennedy Space Center, additional fencing and lighting will be installed at the Orbiter Modification and Refurbishment Facility, Operations and Checkout Building, Vertical Processing Facility, Shuttle Landing Facility, Utility Annex and other essential operation facilities in the Launch Complex 39 (LC-39) area. In addition, vehicle barriers will be installed at Pads A and B in LC-39, the Orbiter Processing Facility and the Vehicle Assembly Building (VAB). Hardened guardhouses will be installed at several facilities in the VAB area.

At Michoud Assembly Facility, additional fencing will be installed along the eastern and southern perimeter.

At Stennis Space Center, additional fencing, access gates, vehicle barriers and lighting will be installed to protect the Test Complex "A" and "B", Space Shuttle Main Engine (SSME) Enging Service Building, Data Acquisition Facility, the canal, lock and bridge area, and other test essential facilities.

At Dryden Flight Research Facility, additional fencing and lighting will be installed to protect the STS facilities.

REFURBISH BRIDGES, MERRITT ISLAND, JOHN F. KENNEDY SPACE CENTER

Refurbishment of the Jay-Jay Railroad Bridge spanning the Indian River is necessary to prevent further deterioration and to ensure delivery of Solid Rocket Booster (SRB) segments for Shuttle, Trident and Titan missions to KSC and Cape Canaveral Air Force Station (CCAFS). There are no alternate methods of delivery for

the SRB segments at the present time. A recent inspection revealed general deterioration of major and minor concrete and steel structural bridge members and made recommendations as to refurbishment and repair.

The Indian River Bridge provides vehicular access over the Intercoastal Waterway for KSC and areas west of the center (Orlando, Titusville, Cocoa, etc.) for personnel, tourists and services, amounting to approximately 17,000 vehicles per day. Recent inspections revealed significant deterioration of various structural elements such as pilings, pile bents, prestressed concrete beams, pile cap tie-back rods, and fenders.

Refurbishment of the Banana River Bridge is necessary to preclude structural failures that could disrupt road and waterway traffic and block one of the major entrances to KSC and access to CCAFS. This bridge is also used for transporting Solid Rocket Booster hardware and launch payloads.

Refurbishment of the Haulover Canal Bridge is necessary to preclude structural failures that could disrupt road and waterway traffic and block one of the major entrances to KSC. Approximately 3,000 vehicles use this bridge every day.

All of the highway bridges have been in continuous operation for over 20 years and have been subject to vigorous vibration, water/humidity intrusion and stress.

Refurbishment of the Jay-Jay Railroad Bridge consists of cleaning spalls/cracks in the concrete substructure and patching with moisture insensitive epoxy grout, replacing bulkhead tie rods, repairing bulkhead piles/caps, and restoring approaches/embankments. After sandblasting the 53 steel bridge spans and the bascule span superstructure, a thorough inspection will be made to determine which spans require replacement. Those judged to be structurally inadequate will be replaced. The remaining spans will be recoated with appropriate protective materials.

Refurbishment of the three highway bridges include work to both the concrete and steel structure. The Banana River and Haulover Canal Bridges work also includes the wing wall parapets, trunion pedestals, bascule piers and fenders and replacement of the bridge grid steel deck. Pilings, prestressed concrete beams, pile caps, deck joints, fender pilings, equipment pedestals, interfacing electrical equipment and miscellaneous other items will be reworked and brought to a reliable, more maintainable condition.

REHABILITATION OF SPACECRAFT ASSEMBLY AND ENCAPSULATION FACILITY II, JOHN F. KENNEDY SPACE CENTER

The SAEF-II facility was completed in 1966 (Figures 2 and 3). The existing roof-mounted AHU's are beyond life expectancy range, and have severely deteriorated due to the harsh salt air environment. Reliability for support of payload customers with critical equipment will be jeopardized without AHU replacement. In addition, the present mounting of the units on platforms above the roof makes roof maintenance nearly impossible. Installation of new energy-efficient AHU's on free-standing structures is the only alternative to assure access to the roof for proper maintenance. The five 24-year-old chillers and controls are worn out and obsolete, require constant maintenance and have replacement parts that are

difficult if not impossible, to obtain. Replacement of these systems and roof is necessary to restore reliability to this critical payload hazardous processing facility.

This project will replace ten existing AHU's with eight new units located on free-standing steel platforms adjacent to the building, install associated ductwork and chilled/hot water piping, and state-of-the-art controls with a programmable logic controller (Figure 4). The existing equipment platforms on the roof will be removed, allowing direct access to the underlying roof. The existing built-up roofing system will be removed and replaced with new insulation and built-up roofing. The five existing chillers and pumps will be replaced with two 300-ton chillers and two pumps inside the building. A new two-cell cooling tower and motor control center will be provided to complete the project.

REHABILITATION OF CENTRAL HEATING/COOLING PLANT (24), LYNDON B. JOHNSON SPACE CENTER

This project is required to assure the reliable operation of the Johnson Space Center (JSC) heating and cooling systems which provide chilled water, steam, and compressed air to 33 major buildings. The CHCP electrical distribution system's capacity is inadequate for existing loads and operations. Existing conditions and anticipated requirements make it imperative that the electrical distribution system be upgraded. The motor control centers (MCC's) and associated 480-volt switchgear are obsolete and replacement parts are difficult or impossible to obtain. The decreasing reliability of the electrical system jeopardizes the operation of approximately 50 motors and numerous other electrically operated devices which directly affect the supply of chilled water, steam and compressed air to the Center's major buildings. Four reliable boilers are required to supply Center steam requirements. Currently, boiler #2 has deteriorated to the point where it is nonfunctional and beyond economical repair and is out of service. A replacement boiler is required to provide operating diversity, capacity, and performance.

This project will replace two existing 12.47-kilovolts (kV)/480-volt dry-type interior transformers with two oil-filled transformers, each rated 2,000-kilovoltamps (kVA). The new transformers will be installed on concrete pads adjacent to Building 24. The transformers will be connected to new interior MCC's by new 3,000-ampere bus ducts. The existing gas and water lines will be relocated to facilitate the installation of the transformer pads and the bus ducts. The existing 1,600-ampere MCC-1 will be replaced with a 2,000-ampere unit; the existing 400-ampere MCC-2 will be replaced with an 800-ampere unit; and the existing 2,500-ampere MCC-3 replaced with a 3,000-ampere unit. The new MCC's will be equipped with main tie breakers. The existing boiler 2 will be replaced with a new water tube boiler with a capacity of 65,000 pounds per hour at 400 pounds per square inch and 600 degrees fahrenheit. The new boiler will be fired with natural gas as the primary fuel and will use No. 2 fuel oil as backup.

CONSTRUCTION OF DATA OPERATIONS FACILITY, GODDARD SPACE FLIGHT CENTER

The Data Operations Facility (DOF) is required to provide space for the development, integration and operation of data operations systems. To support the dramatic growth of information and related communications activities planned for the space Station, Polar Platforms, science activities and other high data rate missions, advanced institutional data and operations management systems are required. Various data systems are being developed to provide these capabilities. These mission management services include monitoring, planning, operations management, engineering data processing, data handling, and data distribution for space-to-ground and ground-to-ground communications. Software systems development and management, data processing equipment integration, and complete system testing will be supported in this facility.

Completion of the facility is required by early 1992 to accommodate the delivery and installation of the electronic systems for software development, systems integration and checkout. This work must be completed in time to allow operational systems checkout prior to the start of Space Station pre-launch activities.

Project provides for the construction of a 75,300 square foot addition to the Technical Processing Facility, Building 28. Site development includes building access paving, and expansion of the north parking lot with an additional 140 parking spaces and modifications to the storm drainage and utility systems. The addition will be a two-story steel frame structure with carpeted raised access flooring throughout the addition. The Building 28 complex utility systems, including chilled, domestic, and fire protection water, steam lines, and sanitary sewers will be modified to accommodate the new addition. Comfort system space conditioning will be provided by a variable volume, constant temperature and humidity air system. Special air conditioning units supplying underfloor cooling air will supplement the comfort system in areas with high cooling loads.

A double-ended substation will be installed in the basement. Telephone systems, cable ways and conduits will be included in the facility.

CONSTRUCTION OF QUALITY ASSURANCE AND DETECTOR DEVELOPMENT LABORATORY, GODDARD SPACE FLIGHT CENTER

The Goddard Space Flight Center (GSFC) is responsible for the development and management of unmanned science and applications earth orbiting satellites, Shuttle attached payloads and Space Station modules and platforms. These mission responsibilities include flight materials selection, control, verification and other materials quality assurance related activities; and the design, development and fabrication of advance semiconductor microelectronic detectors to support specific mission requirements. These two activities are supported by the Materials Quality Assurance Laboratory (MQAL) and the Detector Development Laboratory (DDL). These laboratories are collocated with offices and other non-hazardous functions in the Applied Sciences Laboratory, Building 11 and the Space and Terrestrial Applications Facility, Building 22. Despite

strict adherence to safety procedures it is now critical for continued safe operations to move these functions to a separate facility.

Performing the MQAL functions involves over 5,000 chemicals, forty-eight of which are extremely hazardous. The chemicals include toxic and/or hazardous gases such as hydrogen sulfide, chlorine, propane, acetylene, hydrogen, methane and ammonia. The significant risk of an accident involving chemical spills or gas leakage dictates that these functions be moved to an isolated facility to eliminate the hazard to the health and safety of other employees.

Semiconductor fabrication in the DDL requires various hazardous processing steps including the use of poisonous gases, poisonous chemicals and low-level radiation. These facilities and other nonhazardous laboratory facilities. The new facility would house all of the hazardous processes to eliminate the risk of contamination to other working spaces by laboratory mishaps.

The Quality Assurance and Detector Development (QUADD) Laboratory will be a 61,200 square foot two-level brick and block addition connected to the south wall of existing Building 11.

The MQAL and DDL will be located on the main operating level. These two areas will be physically separated by a 4-Hour five rated concrete masonry wall. A gowning/support area (1200 square feet) will serve as the "link" between the existing Building 11 and the entrance to the DDL in the new facility. The DDL area, (8,000 square feet) will be vibration-controlled. The floor plan includes a class 100 laminar flow clean room within a class 10,000 clean room. The class 100 clean area supports all the detector development and fabrication activities and equipment. The class 10,000 support area will be used for equipment and parts staging activities requiring less stringent contamination control requirements.

The MQAL area (23,300 square feet) includes 18 offices along the perimeter and 20 laboratories in the core. The supporting lower level (27,300 square feet) will be used to house process support equipment, building utility systems, chemical storage and other miscellaneous support functions.

In addition, stair towers, a truck dock (1,400 square feet), a gas emergency power generator, de-ionized water system, compressed air system and a full complement of industrial processing gases will be provided. Other supporting utilities such as electric power, communications, chilled water, steam, domestic water, gas, storm drain, sanitary sewer, will be extended from existing Center systems to support this facility.

MODERNIZATION OF SOUTH UTILITY SYSTEMS JET PROPULSION LABORATORY

The Jet Propulsion Laboratory (JPL) Facilities Master Plan provides unified development for the phased installation of supporting utility systems necessary to service new site developments as well as existing facilities. Therefore, this utility corridor is a vital requirement to effectively support the buildings under construction as proposed in the Master Plan.

The JPL utilities services range from "marginally adequate" to "totally inadequate". The Laboratory's sanitary sewer system was installed by the U.S. Army Corps of Engineers in 1956 for a 1,500 person population. Many lines are broken, cracked, displaced or

plugged; others are overloaded and totally inadequate for today's 7,500-person population. The present water system is only marginally adequate for fire-fighting. New cooling water distribution lines will eliminate most local cooling towers and circulating and cooling pumps in the area south of Mariner Road and west of the Edison substation. Additional power conduits will permit proper balancing of the load in various areas of the laboratory, and allow for more reliable load management. The communication conduits between the main gate and Surveyor Road, via Mariner Road, are full and additional circuits for new facilities are not possible. Urgent needs are now solved by makeshift installation of new conduits and the system has become a maze of conduits and cables. Storm drains inlets, are also required to properly accept lateral drain elements from new site developments. This project is the first critical step to initiate the functional restoration of JPL's utility system.

Included is the following:

- A new sewer collection and removal system consisting of trunk lines and connections serving the southerly and southeastern areas of the Laboratory. Approximately 1,800 feet of 12" vitrified clay pipe (VCP), 125 feet of 10" VCP, 500 feet of 8" VCP, and 50 feet of 6" VCP in addition to 10 manholes and 12 points of connection to existing lines will be installed.
- A new primary lift station using 350 gallons per minute (gpm) vertical pumps and force main installed at and below the West Arroyo Parking Lot and eastward from Building 171.
- 3,100 feet of iron 12" water main from the main gate point of connection around the corridor via the South Gate and over to Surveyor Road, then north to a system connection.
- A new primary 5 pounds per square inch (psi) gas line, composed of 2,000 feet of 8" and 1,200 feet of 6" coated steel pipe, will be installed extending eastward from Oak Grove Drive to Buildings 300 and 302.
- Condenser water supply and return lines, for the future central cooling tower to be built where Buildings 269 and 274 stand, and which will serve all buildings south of Mariner Road and west of the Edison substation, will be installed in the South Corridor. This will include 800 feet of 24" line, 1,400 feet of 16" line, 1,000 feet of 12" line plus 3 dozen valves for further looping and connections.
- Both communications and power conduit and manholes will be installed throughout the South Corridor area and interconnected to the existing net. These total systems will require 18,200 feet of 6" polyvinylchloride (PVC) embedded conduit for power cable, 45,000 feet of 4" PVC communication conduit, 20 power manholes and 25 communications manholes.
- 2,400 feet of 2½" pipe will be laid to support the new air system in the service and fabrication area only.
- Other than surface lateral inlet repairs, no major work to the 24" reinforce clay pipe (RCP) storm drain is anticipated.

CONSTRUCTION OF 40X80-FT. WIND TUNNEL DRIVE MOTOR ROOF, AMES RESEARCH CENTER

Maintenance of the structure in and around the fan drives and fan drive nacelles is very extensive and costly. However, cleaning

and painting is not a satisfactory solution because of the restricted accessibility. This project will provide protection and greatly reduce the necessity for repeated maintenance activities by providing protection from weathering and rain water and eliminate the nesting of birds. The project will also help reduce drive motor noise impact to the immediate outside environment.

Impact of delay.—If the fan drive and fan nacelles are not enclosed and siding and screens are not installed, extensive deterioration of the recently repaired outer structure will continue. Periodic maintenance can be significantly reduced over future years by completion of this project.

Project description.—The project provides for: design, fabrication, and installation of a gable roof over the wind tunnel fan drive system matching the existing roof lines, covering an area of approximately 15,400 square feet; and the design, fabrication, and installation of new sheet metal sidings and screens for the sides of the tunnel under the new roof structure to prohibit birds from nesting, minimize weathering, and dampen acoustic noise to the surrounding environment.

MODIFICATIONS TO THERMO-PHYSICS FACILITIES, AMES RESEARCH CENTER

Current research at these test facilities is critical to NASA's role in aerodynamic and thermophysics research. The 3.5-Ft. HWT is one of the Nation's major hypersonic test facilities and plays a key role in providing essential hypersonic data for the National Aerospace Plane (NASP), aeroassisted orbital transfer vehicles, boost-glide vehicles, and fundamental hypersonic aerothermodynamics Research and Technology (R&T) programs. Numerous requests from outside organizations and a significant in-house program related to the NASP indicate that testing in this facility will make significant contributions to advancing the technology needed to make the NASP operational.

Modifications to the Arc Jet Tunnels are required to extend test capabilities, and improve the accuracy and repeatability of test data acquisition. The air and argon mass flow systems, the operator benchboards and central control panels, and the power supply control system must be upgraded to support the above programs and provide a safer and more efficient research facility.

Modifications to the 3.5 Ft. Hypersonic Wind Tunnel include replacing the alumina pebble bed heater core with a bed matrix of alumina cored brick, new ceramic brick sidewall insulation to replace damaged bricks, a new structure to replace the existing grate, the 12-inch heater stack valve to be replaced with a new flanged-ball style valve, and two vent valves to be replaced with flanged, ballvalves with pneumatic actuators. Also custom-made heater isolation discharge valve will be extensively modified, and all heater thermocouples, combustion control mass flow meters and stack gas analyzers will be replaced. A new microprocessor controls system will be installed, and the existing model support insertion mechanism will be modified.

Modifications to the Arc Jet Tunnels include installation of new air and argon mass flow control and instrumentation systems. The

existing power supply control system will be upgraded to a closed-loop automated system.

MODIFICATIONS TO 14 X 22 SUBSONIC WIND TUNNEL (1212C), LANGLEY RESEARCH CENTER

Recent experimental results obtained in the Langley Vortex Research Facility (VFR) have shown that rate of descent is a very important parameter in analyzing ground effects. Flight data has shown that aircraft undergoing high-rate maneuvers can experience engine compressor stalls due to flow problems associated with the high incidence flow entering the engine inlets. The next generation of fighter aircraft will be required to perform short take-offs and landings. In addition, they must possess extreme maneuver capability. Both parameters are critically important to the development of these aircraft. While rate-of-descent testing is currently possible in the VRF at low free-stream velocities and with a very low productivity rate, there exists no capability for obtaining large amplitude, high-angular-rate information.

In order to obtain experimental wind-tunnel results with rate of descent, large amplitude and high-rate angular motions, a new model support system is needed. This system will have the capability to provide vertical motion for rates-of-descent up to 12 ft/sec and pitching motion for angular rates up to 60 deg/sec. The system will be computer controlled and hydraulically powered to provide a range of vertical speeds and angular rates which can be used either in combination or separately as required by test objectives.

This project will provide a new computer controlled model support system, powered by a 5000-psi hydraulic system to provide vertical velocities up to 12 ft/sec and pitch angular rates up to 60 deg/sec. Vertical and pitch motions will be commanded separately or in combination as required by the test program. The complete support system consists of a new vertical post assembly and drive mechanism, a new model support cart to provide the required system stiffness and impedance, and provisions for a future 8-Ft X 8-Ft moving-belt ground plane located ahead of the post in the floor of the cart.

MODIFICATIONS TO NATIONAL TRANSONIC FACILITY FOR PRODUCTIVITY (1236), LANGLEY RESEARCH CENTER

The NTF is the nation's premier transonic wind tunnel for simulation of flight Reynolds numbers for aircraft and aerospace vehicles. However, since the design requirements were specified in the early 1970's, advancements in aircraft technology have occurred which make it practical to use extensive laminar flow for subsonic transport aircraft and extreme attitudes for maneuvering fighter aircraft which result in significant performance gains. The NTF provides a unique capability to achieve full scale Reynolds numbers at transonic speeds. The proposed modifications are required in order to effectively apply this high Reynolds number capability to research and development of the next generation transport and fighter aircraft. The recent "assessment of NASA's major wind tunnel facilities with respect to current and future needs" by the Wind Tunnel Study Task Team identified this capability as a criti-

cal requirement to meet the research and development test needs in the 1990's.

This project includes: a choke at the entrance of the high speed diffuser that will reduce noise levels in the test section and improve flow quality; an automated sting for testing at large angles of attack from 0 to 70 degrees and ± 15 degrees in yaw; a model support system capable of accommodating a normal force of 4,500 pounds at the maximum angle of attack and will change the angle of attack at a rate of 4 degrees per second with a positioning accuracy of 0.1 degree; an enhanced tunnel control system; the addition of a new large liquid nitrogen storage tank; a 3,000 square foot single story structure for model preparation and tunnel support activities; the replacement of an existing transformer with one of increased capacity; and replacement of the existing hydraulic system operating the pitch system with a new pump-accumulator hydraulic source, piping components, and pressure switches.

MODIFICATIONS TO 20-FOOT VERTICAL SPIN TUNNEL (645), LANGLEY RESEARCH CENTER

After more than 40 years of essentially continuous operation, the tunnel requires equipment upgrades to improve test productivity and to eliminate maintenance problems stemming from obsolete and worn out systems. All new high-performance aircrafts designs are tested in the tunnel and these upgrades will minimize test delays and slippages.

Control of the tunnel airspeed is crucial to test efficiency. The current control system, consisting of a manual rheostat and relays, generates serious lags in drive motor response and is prone to malfunction. A modern digital control system, when coupled with a vane support and positioning system, will increase reliability, and will significantly reduce the need for re-runs.

The present rotary balance is over 40 years old and is worn beyond reasonable tolerances, as well as being susceptible to breakdowns. It places serious limitations on model weight and adjustment capability. The new rotary balance will permit greater test efficiency at higher data accuracy levels.

The video system upgrades will improve image resolution, documentation editing and provide a remote analysis station. These improvements will increase test efficiency, reporting and analysis.

Project description.—This project will replace the rheostat and relay-based control system with a modern solid-state digital electronics and provide new wiring from the motor to a new panel including the installation of a new vane support and positioning system; provide high quality read outs of tunnel air speed, motor rpm, and all important status parameters; provide new control console; install a new retractable support arm; and a new high load capacity model positioning system. In addition, a new high-resolution color video camera system with remote positioning will be installed.

REHABILITATION OF CENTRAL AIR SYSTEMS, LEWIS RESEARCH CENTER

The availability of reliable aeronautical propulsion research facilities is critical to the continued development of propulsion systems for subsonic and supersonic transports, hypersonic vehicles,

and other advanced systems for commercial and military applications. Specific justification for each element of this project are:

A. A recent inspection of the 125 pounds per square inch gauge (psig) Combustion Air Compressor rotors revealed that more than 40 percent of the rivets are cracked and not able to operate at design loads. To assure that this system provides safe and reliable service, the rotors must be replaced.

B. The piping components in the 40 and 150 psig Central Air System are severely corroded and must be replaced to meet the requirements of the National Piping Codes.

C. The intercoolers, aftercoolers, and vessels of the Process System Heat Exchangers are severely corroded and no longer meet the requirements of the National Vessels Codes and must be replaced or repaired.

D. Cooling Towers 1 and 4 are wooden construction and are physically located at a site that makes them highly susceptible to fire. Because there are no backup water systems, loss of these towers would result in major delays. An internal fire protection/suppression system is required to assure integrity.

E. The service air underground piping along Walcott Road must be extended to connect with the Taylor Road lines. This connection will complete the service air network for the central and south areas.

This project provides:

A. Replacement of the deteriorating 125 psig combustion air compressor (C3) riveted rotor with a new welded construction rotor, replacement of compressor bearings and seals, and rewinding the 4,000 horsepower (hp) compressor motor;

B. Removal of existing deteriorated piping and asbestos insulation within the 40 psig Combustion Air System located outside the west wall of the Central Air Equipment Building (64) and installing new piping (ranging from 12" diameter to 54" diameter), new bellows type expansion joints, butterfly valves, pipe supports, and weatherproof covering;

C. Rehabilitate leaking tube bundles and shells in the heat exchanges that meet American Society for Mechanical Engineers (ASME) Boiler and Pressure Vessel Section VIII codes requirements;

D. Retrofit existing wood-framed cooling towers 1 and 4 with a dry, deluge type fire protection system;

E. Install approximately 2,000 ft. of eight inch piping with necessary manholes along Walcott Road to complete the Lewis Center's service air loop.

REHABILITATION OF CENTRAL REFRIGERATION EQUIPMENT, LEWIS RESEARCH CENTER

The central refrigeration system at Lewis Research Center (LeRC) is the only source of refrigeration for the Icing Research Tunnel (IRT), and provides extensive environmental cooling for numerous systems, laboratories, and offices in the Engine Component Research Laboratory. The existing equipment is over 44 years old, and without rehabilitation, modernization and/or replacement, the risk of frequent system failures will significantly increase. The

equipment currently malfunctions on a frequent basis and without attention will become worse with time.

This project includes:

- Compressor rehabilitation and controls, consisting of reconditioning 11 of the existing 13 refrigeration compressors including replacing the seals; reconditioning the bearings, drive motor, gearbox speed increasers, and existing valves; installation of compressor isolation valves for servicing; installation of a hot-gas bypass on each compressor to enhance tunnel warm-up; and installation controls for automatic remote operation of the compressors.
- Building modifications consisting of roof and support structure replacement; installation of a bridge crane; upgrading the control room, building plumbing, heating, and ventilating; control room conditioning; and relocating the natural gas compressor to a new building with utilities outside Building 9.
- Electrical modifications, consists of replacing switchgear, wiring and lighting and building rewiring after the roof is replaced.
- Cooling tower equipment rehabilitation, consists of reconditioning the pumps, and valves.

REHABILITATION OF 8X6 SUPERSONIC AND 9X15 LOW-SPEED WIND TUNNELS, LEWIS RESEARCH CENTER

The 8x6/9x15 wind tunnel complex is NASA's only transonic propulsion wind tunnel used to develop advanced aeropropulsion systems for civilian and military application. Research in this complex includes low speed Advanced Short Takeoff and Vertical Landing (ASTOVAL) for military application, advanced Turboprop initiatives and the development of expendable launch vehicles associated with NASA's space related programs. Future use of the tunnels include research associated with the airbreathing propulsion systems for the National Aero-Space Plane (NASP) and the Air Force Advanced Tactical Fighter (ATF).

Quality of experimental data is of extreme importance for research programs related to the development of advanced propulsion systems both in the low speed turboprop regime and the advanced high Mach number flight regions. In order to properly evaluate these complex propulsion systems, the present tunnel air flow quality requires improvement. Air flow turbulence and acoustic signatures of both tunnels must be optimized. Programs associated with the development of advanced propulsion system for high Mach number flight, such as NASP, will require fuels not presently available. This project will provide for the establishment of a high pressure gaseous oxygen supply system needed to support the NASP research. Accomplishment of this rehabilitation project is mandatory to support these programs.

This project provides for: the rehabilitation of the feeder cables and switching system for the drive motor including replacement of 18 existing feeder cables; replacement or repair of the cable supports; replacement of termination and insulation system components at the transformers and drive motors; and repair of the cable tunnel. Also included is the addition of new motor starters and protective devices. The rehabilitation of the Air Dryer Reactivation

System includes replacement of systems components and installation of additional alumina dryer medium. The modification of tunnel flow path aerodynamic components includes installation of flow deflector turning vanes and flow straightener structures and screens within the tunnel flow path ducting, and new fairings for the compressor inlet and air dryer discharge. Other modifications include: a tunnel model fuel supply system to supply high pressure oxygen gas to the model test chamber; generic mechanical support systems, hydraulic and pneumatic service systems with the controls necessary to provide an off-line model preparation and checkout capability; and the addition of an equipment room for the 9x15 LSWT.

REHABILITATION OF HYPERSONIC TUNNEL, PLUM BROOK STATION (PBS),
LEWIS RESEARCH CENTER

The Hypersonic Tunnel (HT) is the largest, non-vitiated hypersonic propulsion facility in this country. The tunnel is a blow-down, free-jet facility capable of Mach 5, 6, and 7 with true temperature, true altitude, and true air composition simulation. Run times ranges from about 45 seconds to five minutes. Although the facility was initially constructed for large-scale propulsion testing, its unique capabilities make it suitable to support large-scale aerodynamics and thermal structures testing. Restoration of its original Mach 5 to 7 free-jet capability is essential to support planned hypersonic programs. This facility is an integral and critical component for exploring new technologies such as the National Aero-Space Plane (NASP) which involves development of an advanced air-breathing propulsion system far beyond current capabilities.

Future generic hypersonic and high-speed technology efforts will also require the capabilities of the HT. This long term research effort will explore a large number of research problem areas including inlets and ducting, combustors, nozzles, thermal management, propulsion management and component integration and validation.

This project will rebuilt the gaseous nitrogen (CN_2) induction heater, modify the hot train components, install a new radiation shutter valve, refurbish the test chamber and steam ejector train, and restore the facility buildings. Various support systems such as the domestic water, industrial water, cooling tower water and carbon dioxide (CO_2) fire suppression systems, building heating, ventilation, and air conditioning (HVAC) and control room pressurization systems will be rehabilitated. To generate the high Mach No. air flows, the GN_2 rail car system, the gaseous oxygen (GO_2) system storage bottles, piping and liquid oxygen (LOX) vaporizer, and demineralized water cooling tanks, pumps, and piping must be repaired.

In addition, several essential support buildings and systems must be rehabilitated including the steam boiler Building (5231), and the steam accumulators and distribution piping. Existing deteriorated asbestos insulating on the steam lines and components will be removed and disposed of per Environmental Protection Agency (EPA) guidelines. Also, the liquid nitrogen (LN_2) Transfer Building (3233), vaporizer and piping must be reconditioned to support the test facility rail car and storage bottles.

The B Control Building (5411) requires modernization and restoration of the control and data acquisition systems. Also a new smoke detector and a wet pipe fire sprinkler system will be installed in the control bay area.

REPAIR AND MODERNIZATION OF THE 12-FOOT PRESSURE WIND TUNNEL AMES RESEARCH CENTER

The 12-Foot Pressure Wind Tunnel is a subsonic pressure wind tunnel of national importance which has provided critical high Reynolds Number test capability to NASA, DoD, and the U.S. aircraft industry since 1946. The tunnel has an exceptionally low free stream turbulence level, high quality flow, wide range of flight regimes, and large test section capability for high fidelity models. Since 1965, essentially every military aircraft and civil transport has been tested in the 12-Foot Pressure Wind Tunnel. The discovery of severe, unrepairable weld defects forced the derating of the tunnel to one atmosphere of pressure in September 1986 to preclude the possibility of a catastrophic failure. Without repair of the pressure shell for six atmosphere pressure operation, the 12-Foot Pressure Wind Tunnel cannot be used to provide critical high angle of attack, high lift, and laminar flow data for the development of the Nation's advanced military and commercial aircraft.

The 12-Foot Pressure Wind Tunnel is a high-demand facility with tests typically scheduled eight to 16 months in advance with two-shifts-per-day operation. During its operation, the productivity was severely limited because the entire tunnel circuit had to be depressurized for model changes or adjustments. In addition, the inability to assemble check out, and calibrate models outside the test section and the use of outdated and obsolete model support systems and controls severely hampered and limited efficient utilization of the tunnel. The modernization portion of this project will result in a significant increase in productivity with installation of a test section pressure isolation system, a modern measurement and automation system, and dedicated model preparation and calibration areas.

This increment includes the replacement of the pressure shell and support structure, and the installation of a new spherical rotating test section plenum to provide isolation allowing model access without depressurizing the entire tunnel. This will markedly increase productivity and reduce the cost per test. The new shell will be constructed as an American Society for Mechanical Engineers (ASME) code-stamped vessel certified for six atmospheres operation. New model handling systems and supports; main drive power increase from 12,000 hp to 15,000 hp; a new solid state speed control; enhanced Mach Number and Reynolds Number control by modifying the countervane, inlet guide vane and main drive speed controls; and installing a new internal radiator for airstream cooling. The existing air flow cooling system will be replaced, including piping, valves, pumps, cooling tower, and controls. Modern tunnel automation and system controls will be installed to provide state-of-the-art feedback and distributed control of all systems from one central control location. The tunnel support building will be modified to include a second story addition. Two new model preparation rooms will be provided to allow buildup and checkout of

models prior to installation in the test section thereby increasing tunnel productivity. The existing control room will be modernized to include raised computer flooring, visual access to the model staging area, human factors-engineered control consoles, lighting, power, and air-conditioning as required. A new computer support room and technical shops with supporting utilities will also be included. Also, the roof of the existing test section building will be raised to accommodate installation of a new 20-ton bridge crane.

CONSTRUCTION OF AUTOMATION SCIENCES RESEARCH FACILITY, AMES RESEARCH CENTER

Public Law PL 98-371 of July 18, 1984, (Department of Housing and Urban Development-Independent Agencies Appropriation Act 1985) directs NASA to conduct research in advanced automation technologies to be implemented not only to promote the safety and efficiency of the Space Station but also to enhance the technical and scientific base for terrestrial applications. In response, NASA has established the Ames Research Center as the lead center to focus on artificial intelligence and systems autonomy research to be applied to space flight, aircraft automation and future scientific missions.

Ames possesses a nucleus of some of the nation's best young engineers and scientists in artificial intelligence and architecture for advanced automation. The Ames team is probably the strongest governmental artificial intelligence research group in the country today.

Existing program support activities are currently housed in part of Building N-244. However, as the program is fully staffed, the number of personnel will grow significantly, far exceeding the capacity of the current space. Temporary facilities will be used to meet short-term needs, but beyond FY 1991, those will not be adequate. Building and integrating this new facility with the Human Performance Research Laboratory (HPRL) will allow greater interaction between the two disciplines and provide for more effective incorporation of automation and autonomous systems into the Space Station and future space and aeronautics programs. Benefits include enhanced functional reliability and capability, increased crew and mission safety and a reduction of human resources necessary to operate scientific and space missions. The program requires high fidelity testbeds and direct access to symbolic computing facilities which this project will provide.

The new facility will be a 45,200 square foot, two-story facility adjacent to the Human Performance Research Laboratory (HPRL). Existing HPRL high bay, conference room, utilities and lobby space will be shared by both facilities. The building will be a moment resisting steel-frame structure with cement plaster exterior. Site work will include a new parking area, relocation and extension of Hunsaker Road, landscaping and site drainage. Five major laboratories are to be provided as follows: Artificial Intelligence, Computer Science, Optical Information Processing, Electronics and Systems Integration. All laboratories will be provided with raised computer floors and heating, ventilating and air-conditioning. Office and staff support space for 150 people will be provided. Also to be provided are conditioned power, grounding, data communications,

security and fire systems and a variable volume air-conditioning system for both the office and non-laboratory areas.

CONSTRUCTION OF SUPERSONIC/HYPERSONIC LOW-DISTURBANCE
TUNNEL (1247D), LANGLEY RESEARCH CENTER

All existing wind tunnels operating above approximately Mach 2.5 have high acoustic disturbance levels which extend up to frequencies as high as 300 kilohertz (kHz). This noise dominates basic flow mechanisms and preclude viscous flow studies. This proposed tunnel will provide a very significant improvement in aerodynamic testing because it will provide test-section disturbance levels of 10 to 100 times less than those typical of existing tunnels. The proposed tunnel's capabilities will produce the criteria for determining data validity and quantifying disturbance related adjustments. Therefore, the proposed tunnel will eliminate testing conducted in existing wind tunnels under conditions that produce questionable or invalid results due to the dominance of acoustic disturbances.

The proposed tunnel will be similar to existing pilot tunnels, but scaled up by a factor of about three. Two very important advantages for conducting research in the proposed tunnel rather than in the pilot tunnels are that: (1) these thicker boundary layers will be more accessible for detailed probing, and (2) the thicker boundary layers will be less sensitive to "built-in" wall disturbances such as machining errors, wall waviness and roughness.

The proposed facility will have a low-disturbance test core about three times larger than that of the pilot facilities. The facility will be designed in a modular fashion to allow interchangeable nozzles of Mach 3.5 and Mach 6.0 to be utilized. A new 8-foot-diameter by 25-foot-long settling chamber with flow straightening, noise attenuation, and turbulence reduction devices will be provided. The chamber is to be connected to an existing heater to be provided with a new tube bundle, and a modified and improved air supply system capable of more than the required mass flows, pressures and temperatures which are already controlled by a master computer. Transducers for pressure and temperature will be added and 1-micron particle filter system will be installed.

The new Mach 3.5 nozzle will be a two-dimensional rapid-expansion nozzle with boundary-layer bleed-off. The Mach 6.0 nozzle will be an axis-symmetric contoured nozzle approximately $3\frac{1}{2}$ meters long and 0.6 meter exit diameter. A new isolation valve is to be provided between the plenum and sphere. The required vacuum system with pumps and spheres already exists. The test section and model injection system will be installed to position the model in the forward test core. Also a new variable-air diffuser with an isolation valve will be connected to a second existing vacuum system. The exhaust to the atmosphere will be routed through an existing noise muffler.

MODIFICATION FOR SEISMIC SAFETY, GOLDSTONE, CALIFORNIA, JET
PROPULSION LABORATORY

The Goldstone Deep Space Communications Complex (GDSCC) is located in the Mojave Desert in an area identified in the Uniform Building Code as Seismic Zone IV, which is the highest risk classification. These operations critical buildings were designed and constructed prior to the latest design code when the Goldstone area

had the lower risk classification of Zone III. Substantially increased structural strengthening of buildings and bracing and anchoring of utility and building related equipment are required to reduce hazards to personnel and vital space mission support systems.

Operations planning for GDSCC has determined that it is more economical to close the old Apollo site, Deep Space Station (DSS-16) facilities and consolidate the functions at other sites in lieu of making extensive seismic modifications at this site. Data handling functions will be relocated to the Mars site. Additional space is also needed in this facility to accommodate the electronic equipment and operations staff now temporarily located in trailers.

This project provides modifications for seismic safety in G-24 Echo Power Plant, G-51 Venus Operations, G-60 Venus Laboratory and Offices, G-81 Mars Power Plant and Switchgear. Structural modifications to the buildings include the strengthening of shear walls with steel mesh reinforced concrete laminate and reinforcing of the roof to wall connections. Bracing and anchoring of electrical and mechanical building equipment is also included. This project also includes the construction of a 54 by 60 foot addition to the east side of Building 86 Mars Operations Control with a full height cable plenum and a computer floor system to safely accommodate equipment and operating personnel. Heating, ventilating, air-conditioning, and fire protective systems will be modified, and electrical power, lighting, grounding and communications systems will be provided.

FISCAL YEAR 1990 REQUESTS

SUMMARY—REPAIR

Summary of project amounts by location:

	<i>Amount</i>
Ames Research Center	\$3,080,000
Goddard Space Flight Center.....	1,655,000
Jet Propulsion Laboratory	1,920,000
Johnson Space Center	2,670,000
Kennedy Space Center	3,375,000
Langley Research Center.....	3,405,000
Lewis Research Center.....	3,110,000
Marshall Space Flight Center.....	1,650,000
Michoud Assembly Facility.....	2,610,000
Stennis Space Center.....	975,000
Wallops Flight Facility	2,110,000
Miscellaneous Projects Not in Excess of \$150,000 Each	1,440,000
Total.....	28,000,000

These resources will provide for large repairs to facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in the request are those facility repair needs for FY 1990 that can be predicted at the time of the submission of these estimates and are not to exceed \$750,000 per project. The thrust of this program is to restore facilities and components thereof, including collateral equipment, to a condition substantially equivalent to their originally intended and designed capability. The request includes the substantially equivalent replacement of utility systems and collateral equipment necessitated by incipient or actual breakdown. This work also includes major preventive measures which are normally accomplished on a cyclic schedule of greater than one year.

A major portion of the agency's facilities exceeds 25 years in age, and increases in repair requirements are to be expected. Maintenance and repair costs for mechanical and electrical systems in a typical building are almost three times higher during the 16- to 30-year period of a building's life than they are during the initial 15 years. Many electrical and mechanical components reach the end of their serviceable or economic life at about the 15 to 20 year point and should be replaced in the interest of long-term economy. Continued piecemeal repair of these components is usually more costly in the long run than replacement at the end of the economic life of the original components. Approximately 75 percent of NASA's physical plant is in the 16- to 30-year-old category.

A major thrust of this repair program is to help preserve the capabilities of the agency's \$4.0 billion physical plant. An analysis of each project clearly indicates that this work must be addressed and progressively accomplished. Otherwise, risks are increased and future repair costs will be significantly greater. More importantly, there will be increased breakdowns, interruption of critical operations and costly unscheduled repairs incurred.

This program includes only facility repair work having an estimated cost not in excess of \$750,000 per project. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance and repair activities. Repair projects estimated to cost more than \$750,000, are included as separate discrete projects in the budget request.

FISCAL YEAR 1990 REQUESTS

SUMMARY—REHABILITATION AND MODIFICATION

Summary of project amounts by location:

	<i>Amount</i>
Ames Research Center	\$2,270,000
Dryden Flight Research Facility	1,230,000
Goddard Space Flight Center	3,220,000
Jet Propulsion Laboratory	2,460,000
Johnson Space Center	3,500,000
Kennedy Space Center	3,990,000
Langley Research Center	3,335,000
Lewis Research Center	3,615,000
Marshall Space Flight Center	3,900,000
Michoud Assembly Facility	1,295,000
Stennis Space Center	2,200,000
Wallops Flight Facility	1,865,000
Various Locations	1,400,000
Miscellaneous Projects Not in Excess of \$150,000 Each	1,720,000
Total	36,000,000

REHABILITATION AND MODIFICATION OF FACILITIES, NOT IN EXCESS OF \$750,000 PER PROJECT, VARIOUS LOCATIONS

These resources will provide for the rehabilitation and modification of facilities at NASA field installations and Government-owned industrial plants supporting NASA activities. Included in this request are those facility rehabilitation and modification needs for FY 1990 that have been fully identified at the time of the submission of these estimates and are estimated not to exceed \$750,000 per project. The purpose of this program may include some restoration of current functional capability but also includes enhancement

of the condition of a facility so that it can more effectively accomplish its designated purpose or increase its functional capability.

Based on the initial investment costs, the NASA Capital Type Property totals approximately \$7.5 billion of which the physical plant comprises some \$4.0 billion. A continuing program of rehabilitation and modification of these facilities is required to accomplish the following:

- a. Protect the capital investment in these facilities by minimizing the cumulative effects of wear and deterioration.
- b. Ensure that these facilities are continuously available and they operate at peak efficiency.
- c. Improve the capabilities and usefulness of these facilities and thereby mitigate the effects of obsolescence.
- d. Provide a better and safer environment for all personnel.

This program includes only facility rehabilitation and modification work having an estimated cost not in excess of \$750,000. The work is of such a nature and magnitude that it cannot be accomplished by routine day-to-day facility maintenance or by related facility work efforts that are provided for in other than CoF estimates.

FISCAL YEAR 1990 REQUESTS

SUMMARY—MINOR CONSTRUCTION

Summary of project amounts by location:

	<i>Amount</i>
Ames Research Center.....	\$475,000
Dryden Flight Research Facility.....	480,000
Goddard Space Flight Center.....	370,000
Jet Propulsion Laboratory.....	960,000
Johnson Space Center.....	1,155,000
Kennedy Space Center.....	1,560,000
Langley Research Center.....	1,335,000
Lewis Research Center.....	940,000
Marshall Space Flight Center.....	980,000
Stennis Space Center.....	980,000
Wallops Flight Facility.....	400,000
Miscellaneous Projects Not in Excess of \$150,000 Each.....	365,000
Total.....	10,000,000

These resources will provide for minor facility construction at NASA field installations and Government-owned industrial plants supporting NASA activities. Each project included in this program is estimated to cost not more than \$500,000 and involves either the construction of new facilities or additions to facilities. The FY 1990 request of \$10,000,000 will improve the usefulness of NASA's physical plant by changing the utilization of or augmenting the capabilities of various facilities. Included in this request are those programmatic and institutional projects that are essential to the accomplishment of mission objectives.

The configuration of NASA's physical plant necessarily must respond to changes in utilization and adaptations required by changes in technology or in mission needs. Demands are generated by research, development, test, and similar activities. Specific justification for each minor construction project is provided under "Project Cost Estimate."

FISCAL YEAR 1990 REQUESTS

SUMMARY—FACILITY PLANNING AND DESIGN

	<i>Amount</i>
Regular requirements:	\$13,900,000
Master Planning.....	300,000
Sustaining Engineering Support.....	1,400,000
Preliminary Engineering Reports and Related Special Engineering Support.....	3,600,000
Final Design.....	8,600,000
Other requirements.....	12,400,000
Space Flight Facility Planning and Design.....	4,800,000
Aeronautical Facilities Revitalization Facility Planning and Design.....	5,800,000
Space Station Freedom Facilities Planning and Design.....	1,800,000
Total.....	26,300,000

FACILITY PLANNING AND DESIGN

The funds requested in this estimate are required to provide for the following advance planning and design activities related to facilities and projects:

a. The accomplishment of necessary development and master planning for field installations and, where not otherwise provided for, the provision of continuing engineering support and special engineering management and other services.

b. The preparation of preliminary engineering reports, cost estimates, and design and construction schedules.

c. The preparation of final construction plans, specifications, and associated cost estimates and schedules required to implement construction projects.

d. The accomplishment of facilities and other investigations, studies and reports, where not otherwise provided for.

Regular requirements encompass the basic purposes outlined above. The "other requirements," while also in support of "regular" purposes, cover those special needs related to large, complex projects or specific programs considered to represent high potential future construction requirements for which early definition is essential. The large projects require more planning and longer lead time. Much of this planning must be completed prior to inclusion of the project in a budget request.

FISCAL YEAR 1990 REQUESTS

SUMMARY—ENVIRONMENTAL COMPLIANCE AND RESTORATION

Summary of project amounts by location:	<i>Amount</i>
Ames Research Center.....	\$900,000
Dryden Flight Research Facility.....	1,000,000
Goddard Space Flight Center.....	2,750,000
Jet Propulsion Laboratory.....	1,310,000
Johnson Space Center.....	1,960,000
Kennedy Space Center.....	1,580,000
Langley Research Center.....	1,000,000
Lewis Research Center.....	3,000,000
Marshall Space Flight Center.....	3,000,000
Michoud Assembly Facility.....	1,650,000
Stennis Space Center.....	550,000
Wallops Flight Facility.....	590,000
White Sands Test Facility.....	2,700,000
Various Locations.....	290,000
Miscellaneous Projects Not in Excess of \$150,000 Each.....	2,880,000

Studies, Assessments, and Design.....	2,090,000
Remedial Investigations, Feasibility Studies, and Related Engineering	2,750,000
Total.....	30,000,000

ENVIRONMENTAL COMPLIANCE AND RESTORATION PROGRAM, VARIOUS LOCATIONS

These resources will provide for studies, assessments, remedial investigations (RI) feasibility studies (FS), related engineering, design and remedial projects for environmental compliance and restoration measures at NASA field installations and Government-owned industrial plants supporting NASA activities. The purpose of this program is to enable compliance with mandatory statutory environmental requirements and standards. The resources authorized and appropriated pursuant to this program may not be applied to other activities. The program includes such measures as studies or assessments to determine current status and options for remedial action, prescribed RI's and FS's as required by Federal environmental restoration, hazardous waste removal and disposal, cleanup and closures and removal of unsafe buildings and debris.

Proposed environmental compliance and restoration projects and activities for Fiscal Year 1990 total \$30,000,000 which has been distilled from requests of approximately \$54,000,000. This program represents only a modest request in relation to total requirements for environmental compliance and restoration that must be implemented within the next several years. Based on relative urgency and potential health hazards, the following listed projects are the highest priority requirements and are currently planned for accomplishment in FY 1990. Deferral of these necessary remedial measures would make it impossible for NASA to comply with environmental law and will cause shutdown of critical NASA operations by individual State or Federal environmental authorities. Studies, assessments, and design costs are approximately \$2,090,000. To comply with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Superfund Amendments and Reauthorization Act (SARA) regulations, necessary RI's and FS's must be performed. The estimate cost for these activities is \$2,750,000. Projects estimated to cost not in excess of \$150,000 have not been described or identified by specific location. The estimated cost of these projects is \$2,880,000.

For those projects greater than \$150,000, the following broad categories of effort will be undertaken in Fiscal Year 1990. As studies, assessments, RI's FS's, and designs progress, it is expected that priorities may change and revisions of the activities and projects may be necessary.

FISCAL YEAR 1990 REQUESTS

SUMMARY—PRIVATIZATION

Office or Space Station:	Amount
Construction of Neutral Buoyancy Laboratory, Johnson Space Center.....	\$30,000,000
Construction of Space Station Processing Facility, Kennedy Space Center	43,000,000

Office of Space Flight:	
Advanced Solid Rocket Motor Production and Test Facility, Yellow Creek, Mississippi	60,000,000
Office of Space Science and Applications:	
Construction of Observational Instruments Laboratory, Jet Propulsion Laboratory	14,000,000
Total	147,000,000

CONSTRUCT NEUTRAL BUOYANCY LABORATORY, LYNDON B. JOHNSON SPACE CENTER

This project provides for the construction of a Neutral Buoyancy Laboratory (including 225 x 125 x 60 feet water tank) at the Johnson Space Center (JSC) to meet the requirements for extravehicular activity (EVA) simulations for engineering evaluations, astronaut training and EVA procedures development and validation for the Space Station era. The facility also will provide real-time mission support for anomalies during Space Station assembly and operation.

A facility is required to meet the requirements for EVA simulations for astronaut training and procedures development for assembly and support of the Space Station program. This program utilizes extravehicular activity as the baseline operational capability for structural buildup and assembly tasks. These extensive operations depend on the EVA capabilities and successful task completions. Extravehicular activities have previously been successfully developed using neutral buoyancy simulations in water tank facilities, but not of the size, complexity, and duration and periods needed for the Space Station. Astronauts in space suits must be able to perform space-related EVA operations in ground based facilities in such a manner that the results will correlate closely to the actual on-orbit task performance. Existence water tank facilities were sized for earlier program requirements and are too small for the larger Space Station flight hardware assemblies. The rate of EVA development operations, astronaut training and hardware verification are increased significantly by the Space Station requirements. The Neutral Buoyancy Laboratory will accommodate the very large space hardware and will provide realistic EVA development activities and operations.

The Neutral Buoyancy Laboratory must be operational to support Space Station engineering proof-of-design concepts and validate EVA assembly task operations. Additionally, the Neutral Buoyancy Laboratory will support the Space Transportation System (STS) Orbiter astronaut tasks for Space Telescope and other STS servicing missions. It is not cost-effective to expand the size of existing facilities at JSC and MSFC, and the full scale training activities achievable in this new facility are vital to development of the Space Station.

This project provides a laboratory building of approximately 155,800 square feet (sq. ft.), constructed of steel-framing with metal siding. Inside the laboratory, a tank approximately 225 feet (ft.) long, 125 ft. wide, and 60 ft. deep and an adjacent area of 375 ft. by 175 ft. will be provided. Approximately 27,000 sq. ft. at the ends of the building will be utilized as test article mockup assembly space. The facility also will include mockup handling cranes, hyperbaric

and decompression chambers, tank pumping and filter equipment, electrical power, a computer area, connection to the JSC utility control system, fire detection and suppression, lighting and heating and air-conditioning systems. Included in this facility will be a three-story technical support area approximately 30 ft. by 300 ft. housing test support rooms, laboratories, equipment storage areas and a visitors viewing area. In addition, a one-story utility support area of approximately 8,400 sq. ft. will provide space for mechanical and electrical equipment. Other construction work includes service drives, fencing, aboveground and underground utilities, main and secondary service entrances, sidewalks, an outside mockup storage area of approximately 24,000 sq. ft., a cooling tower, transformer yard, water storage tanks, parking for approximately 200 vehicles and landscaping.

CONSTRUCTION OF SPACE STATION PROCESSING FACILITY, JOHN F. KENNEDY SPACE CENTER

This project provides for construction of the Space Station Processing Facility (SSPF) for the pre-launch and post-landing nonhazardous processing of the various Space Station program elements at the Kennedy Space Center (KSC). This increment provides the site preparation and basic building structure for the high bay, airlock, intermediate bay, off-line labs, operations control area, support areas and final site work. A follow-on increment in FY 1991 will complete the facility.

Pre-launch processing is necessary to accomplish post shipment inspection and verification of Space Station elements prior to launch, to verify element-to-element interfaces, to perform final servicing and to verify on the ground, to the extent practicable, the capability of the elements and systems to function as planned in orbit. Unlike payloads/experiments aboard short duration Space Shuttle missions, Space Station elements will be in orbit for extended periods and cannot be easily or inexpensively returned to Earth for correction of system problems or malfunctions. Therefore, ground processing of Space Station elements is critical to achieving the program objectives.

Processing of elements/payloads will begin with their delivery at KSC. Elements are outfitted and assembled at the factory but final assembly, servicing, integration and verification can only be accomplished at KSC. The final processing operation will install the element in the Shuttle payload canister for transportation to the launch pad and insertion into the Orbiter's cargo bay for launch. After the Space Station becomes operational, the need for processing elements will continue as elements are returned from orbit for refurbishment, retrofitting and resupply. Both U.S. and international logistic modules will require repeated processing.

After extensive studies and analysis of the Space Station processing requirements, it was determined that the most cost-effective and efficient manner to provide nonhazardous processing of Space Station elements and their experiments was to build a new facility. Use of the existing KSC facilities, including the Operations and Checkout Building, was carefully studied and was determined not suitable due to their configurations and continuing requirements for Spacelab and other programs.

The SSPF has been sized to support the following nonhazardous processing during Space Station assembly and operational phases:

1. Initial components of the Space Station—final assembly, servicing, final tests and closeout.
2. Logistics and Resupply Operations—logistic module loading and unloading, materials handling and staging, processing and storage (minimum payload logistics associated with Space Station logistic module payload resupply only).
3. Payload Operations—off-line lab, minimal logistics, staging, storage, prelaunch integration and post-landing deintegration areas.

Location of this facility close to the existing Operations and Checkout Building will provide the opportunity for joint use of specialist checkout personnel (Figures 1 and 2).

The Space Station Processing Facility will enclose a total gross area of approximately 398,000 square feet (sq. ft.) and house a permanent staff of over 1,500 civil service, contractor, user and international personnel (Figure 3). Areas will include approximately 73,000 sq. ft. of high bay and intermediate bay floor space for parallel processing of eight Space Station (SS) elements in a class 100,000 (100K) clean, controlled environment (Figure 4). Two facility overhead cranes (30-ton, 50-foot maximum hook height) will be provided in the high bay. A 4,178-sq.-ft. air lock (class 100K clean) will provide high bay access. One 15-ton bridge crane with 45-foot hook height will span the width of the airlock.

The high bay will support module/element processing and canister/strongback operations, the intermediate bay will provide rack and experiment areas. The processing areas will be provided with compressed air and vacuum systems, gaseous nitrogen and gaseous helium (GN_2 and GH_2) distribution systems, gaseous vent systems for ammonia, high pressure general purpose and pressure experimental applications vent systems, and an ultraviolet/infrared (UN/IR) fire detection system.

The three-story off-line support area will contain approximately 320,000 sq. ft. of operational area (Figure 4). Areas within the support area include 9,532 sq. ft. for customer support; 6,772 sq. ft. for international support; and area for off-line laboratories and experiment, payload and rack testing. The remaining space includes operations support areas for schedule and quality control (QC) rooms, shop supervision, documentation and control room area, laboratories and office space. Also included are various common support areas such as mechanical/electrical equipment rooms, electrical communication rooms, cafeteria, rest rooms, elevators, stairwells and corridors.

This increment will include general site work and site utilities, the building foundations, floor slabs, structural steel, roofing, exterior walls, and long lead mechanical and electrical equipment. Site work will include construction of storm drains and GN_2 mains and other mechanical utilities; sanitary, fire and potable water will be tied into existing utilities. The power and communications duct banks will also be constructed.

The follow-on increment of funding includes mechanical and electrical distribution systems, architectural systems and landscap-

ing and parking. Emphasis will be placed on specialized areas to ensure their earlier completion and activation.

CONSTRUCTION OF ADVANCED SOLID ROCKET MOTOR PRODUCTION AND TEST FACILITY, VARIOUS

This project provides for construction of the New Advanced Solid Rocket Motor (ASRM) Production and Test Facilities and the acquisition of the Yellow Creek site from the Tennessee Valley Authority (TVA). Acquisition of the land will be from FY 1989 funds appropriated for this project. ASRM is needed to recover lost payload lift, added mission capability and improve margins of safety and reliability of the Space Transportation System. The Yellow Creek site in Northeastern Mississippi has been tentatively selected as the Government site for the production facilities and Stennis Space Center has been tentatively selected as the Government site for the testing facilities. Final site approval and acquisition will not be made until after an Environmental Impact Statement (EIS) has been completed. Each ASRM contractor proposal includes a private financing option and this FY 1990 CoF budget submission assumes that this option will be selected.

The NASA Authorization Act of 1988 (PL 100-141, October 30, 1987, Section 121) indicated that the Solid Rocket Motor (SRM) Project of the Space Shuttle Program would benefit from competition and directed issuance of an (RFP) for an ASRM. This ASRM will significantly improve the safety and reliability margins of the SRM by better ballistic design to reduce or eliminate about 175 critical failure modes. It also will provide the Shuttle with a significant gain in performance by providing an additional 12,000 pounds of payload capability. Moreover, development of the ASRM will establish a strong technical foundation upon which U.S. leadership in the highly competitive field of solid fueled rockets can be maintained.

Production of the ASRM will require modern and automated facilities with greatly improved manufacturing and quality control processes. The facilities will be designed to produce 16 flight sets of ASRM's per year to ensure meeting Shuttle launch rates. The new plant will incorporate state-of-art computer controlled manufacturing and assembly techniques to enhance the reliability and safety margins of the motor. The present manufacturing process is a labor-intensive process with many opportunities for human error and requires additional inspection effort to ensure achievement of required quality standards. The advanced motor will have a segmented joint configuration which provides better maintainability and lesser risk of failure.

The ASRM acquisition plan recognizes that the production plant is highly dependent on ASRM design features. Accordingly, the contract for design, development, test and evaluation (DDT&E) includes the design and construction of the necessary production and test facilities. This will shorten the time needed to complete the plant and to maximize coordination between motor design and facility design.

The first increment of construction scheduled for FY 1989, depending on location, will include site preparation and development and start of facilities construction. This increment also provides for

the design of the facilities. As a result of the acquisition methodology, detailed facilities development schedules for FY 1990 through 1992 will not be available until a contractor is selected. Contractor proposals are under evaluation by a NASA Source Evaluation Board, with contractor selection scheduled for late spring or summer 1989.

The total facility construction program is phased over four fiscal years and will include manufacturing buildings; test stands; control, instrumentation and data acquisition systems; peripheral equipment and support facilities. All potential offerers have teamed with Architectural/Engineering (A/E) firms and it is expected that each will propose to use a design/build approach for facilities construction. Functions to be included in the total ASRM production and test facilities include.

Production Facilities—Case Refurbishment/Preparation, Nozzle Manufacturing/Refurbishment, Aluminium (AL) & Ammonium Perchlorate (AP) Storage, Oxidizer Preparation, Premix, Propellant Mixing, Cast/Cure, Core Strip/Trim, Tool Cleaning, Final Assembly, Non-destructive Evaluation and Static Test.

Support Facilities—Engineering & Administration, Research & Development, Security, Fire Station/Dispensary, Cafeteria & Training, Hazardous Waste Storage, Waste Treatment, Sewage Treatment, Water Treatment, Laboratory, Metrology, Component Testing, Chemical Laboratory, Central Warehouse, Inert Materials Storage, Base Maintenance/Custodial, Operations and Maintenance, Safe Haven Shelters, Motor Surge, Communications, Meteorology, Motor Shipping/Receiving, Barge Loading, Motor Pool, Power Station, Boiler/Chilled Water Plant and a Control Bunker.

CONSTRUCTION OF OBSERVATIONAL INSTRUMENTS LABORATORY, JET PROPULSION LABORATORY

This project provides for the construction of a multistory 80,000-square-foot laboratory. A controlled environment for assembly, research, and testing of instruments from 1 to over 100 cubic feet and weighing up to 600 pounds will be provided. The Jet Propulsion Laboratory (JPL) is responsible for the development of instruments used in the Earth Surface, Earth Atmosphere, Planetary Exploration and Astrophysics Programs. The present facilities were not designed for the necessary controlled conditions, size or increased number of future space instruments. It is imperative that this facility meet the increased area and environmental requirements for future programs.

The significant growth of observational instruments over the next few years will require a new facility. The facility must house imaging systems, infrared and analytical instruments, microwave observational systems and optical science and applications development activities. It must provide the capability to develop observational instruments operating throughout the electromagnetic spectrum. Such instruments require stringent procedural controls as well as control of temperature, humidity, and particulate contamination during manufacture, assembly, test, and calibration.

In addition the number of instruments requiring processing is increasing steadily. Currently, approximately 10 instruments are in some phase of development and testing. The number is expected to reach more than 20 or more in the 1990's. Also, there is an increase in the size of the instruments e.g., weight, volume, power, data, cost. Current instruments weigh around 30 pounds and occupy about 2 cubic feet. The future instruments will weight around 600 pounds and occupy 100 cubic feet. The general growth in physical size precludes the use of existing facilities. The larger instruments will require cranes, and vehicle transporters, which require a facility with vertical and horizontal clearance for this equipment. Also, instruments are becoming increasingly sensitive and will require improved contamination, temperature and humidity control. Future instruments will need an adequate and safe processing facility which presently does not exist at JPL.

This project will provide for construction of an approximately 80,000-gross-square-foot steel frame building on an open site in the southern sector of JPL, east of Surveyor Road, and south of the Robotics Laboratory, Building 278. The building will include a high-bay assembly area, class 10,000 clean rooms, electronic and optical laboratories necessary for assembly, testing, and calibration, an atmospheric observation laboratory on the roof, and essential support space. The building will be environmentally controlled and fire sprinkled. The clean room ventilation systems will be separate from the central system. Compressed air, gaseous nitrogen, central vacuum systems, liquid nitrogen, and deionized water will be provided. The building electrical systems will include a 480 V and 208 V power distribution system. Grounding will consist of four individual systems: the power system ground, personnel safety equipment ground, electrostatic control ground, and signal reference ground. The communications systems will include fire detection, telephone, utility control, local area networking, and a hardwired instrumentation system. A central plant will be located adjacent to the structure to accommodate two chillers with cooling towers and pumps with a total capacity of 530 tons, liquid and gaseous nitrogen storage tanks, and laboratory vacuum and compressed air pumps.

RESEARCH AND PROGRAM MANAGEMENT

The Research and Program Management appropriation funds the performance and management of research, technology and test activities at NASA installations, and the planning, management and support of contractor research and development tasks necessary to meet the Nation's ongoing objectives in aeronautical and space research. The objectives of the activities funded by the Research and Program Management appropriation are to (1) provide a civil service staff with the technical and management skills to conduct the full range of programs for which NASA is responsible, (2) provide base maintenance of facilities in support of research and development programs, and (3) provide effective and efficient technical and administrative support for the research and development programs. For 1990, an appropriation of \$2,032,200,000 is requested.

During the summer of FY 1988 NASA conducted an in-depth review of its manpower requirements. The results of the study indicated that based on Space Station program needs as well as Research and Technology base requirements NASA would need a significant increase to its current workforce. In discussions with the OMB relative to the results of the manpower review OMB agreed that NASA's FTE ceilings be increased in FY 1989 to 23,734 and to 24,007 FY 1990. Current budget levels will not allow NASA to meet OMB approved higher ceilings, thus this budget is predicated on NASA's ability to fund FTE levels of 23,150 in FY 1989 and 23,846 in FY 1990 including the IG. NASA remains committed to achieving OMB approved ceilings for both FY 1989 and FY 1990. Every possible effort will be made to secure funding so that planned programmatic activities can be realized.

The 1990 Research and Program Management appropriation request provides funding for 23,700 permanent and temporary civil service full time equivalent (FTE) exclusive of the IG eight major installations and Headquarters. This civil service workforce is NASA's most important resource and is vital to future space and aeronautics research activities. Approximately 60% percent of the requested funding provides for the salaries and related costs of the civil service workforce. Two and one half percent is for travel, critical to manage successfully the agency's in-house and contracted programs. The remaining amount of the Research and Program Management appropriation provides support for the research, test and operational facility support, and for related goods and services necessary to operate efficiently and effectively the NASA installations and to accomplish NASA's approved missions.

NASA field centers report to the Program Associate Administrator responsible for the major portion of their technical programs. The principal roles assigned to each installation, based on demonstrated capabilities and capacities to meet NASA's overall program goals, are as follows:

OFFICE OF SPACE FLIGHT

Johnson Space Center.—Management of the Space Shuttle program, including orbiter production and operation; selection and training of astronauts and mission specialists; Space Transportation System Operations including mission planning, operational procedures and flight control; and management of the Space Station truss system, airlocks and nodes, subsystems development, including propulsion and EVA, and operations planning and definition.

Kennedy Space Center.—Launch of Space Shuttle flights; management of the ground operational phase of the Space Transportation System; the preparation and launch of payloads on the Space Shuttle and expendable launch vehicles, and Space Station operational launch readiness planning.

Marshall Space Flight Center.—Management of the Space Shuttle main engine, solid rocket booster and external tank projects; management of the Advanced Solid Rocket Motor (ASRM) and Propulsion system of the Advanced Launch System (ALS); management of the Advanced Propulsion Technology for Earth Orbit applications; management of NASA's activities on the Spacelab project; management of large automated spacecraft projects such as the Hubble Space Telescope; conduct and development of experiments in materials processing in space; and management of the Space Station habitation, logistics and laboratory modules.

National Space Technology Laboratories.—Space Shuttle engine testing; testing for the Advanced Launch System program; Earth resources research and technology transfer; and provision of support service functions for other Government agencies located on site.

OFFICE OF SPACE SCIENCE AND APPLICATIONS

Goddard Space Flight Center.—Development and operation of Earth orbital flight experiments and automated spacecraft to conduct scientific investigations and demonstrate practical applications; management of tracking and data acquisition activities; management of the Delta launch vehicle program; management and launch of sounding rockets and balloons; operation of an instrumented flight range for aeronautical and space research; and development of the Space Station platforms and payload accommodations. The Wallops Flight Facility is an operational element and component installation of the Goddard Space Flight Center.

SUMMARY OF THE BUDGET PLAN BY FUNCTION

	1989 current estimate	1990 budget request
I. Personnel and Related Costs	\$1,171,513,000	\$1,222,040,000
II. Travel	47,116,000	50,957,000
III. Operation of Installation	672,971,000	759,203,000
A. Facilities Services	(270,302,000)	(305,468,000)
B. Technical Services	(166,714,000)	(195,671,000)
C. Management and Operations	(235,955,000)	(258,064,000)
Total NASA	1,891,600,000	2,032,200,000
IG	(8,576,000,000)	8,795,000,000

OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY

Ames Research Center.—Conduct of activities involving experimental and theoretical aerodynamics research, computational fluid dynamics, aeronautical flight research and testing, rotocraft technology, short and vertical takeoff and landing technology, technology for transatmospheric vehicles, planetary probe research, life sciences, human factors, autonomous systems, guidance and control, and operation of an alternate landing site for the Space Shuttle operational missions. The Dryden Flight Research Facility, an operational element and component installation of Ames located in the Mojave Desert, is the site of advanced flight testing and shuttle landings.

Langley Research Center.—Conduct of subsonic aircraft research and technology, emphasizing fuel conservation, safety and environmental effects; hypersonic propulsion; experimental and theoretical aerodynamics; environmental quality monitoring by remote sensing; advanced space systems technology; and research in the areas of structures and materials, guidance and controls, and airframe/propulsion integration of the transatmospheric research and technology program.

Lewis Research Center.—Conduct of aeronautical and space propulsion research and technology, including propulsion for the transatmospheric research and technology program; space communications research and technology; space energy systems research and technology; development of the space station power system; and management of expendable launch vehicle programs.

INSPECTOR GENERAL DETAIL OF CONTENTS BY FUNCTION

I. PERSONNEL AND RELATED COSTS

A. COMPENSATION AND BENEFITS

1. Compensation—

a. *Permanent Positions:* This part of Personnel and Related Costs covers the salaries of the full-time permanent civil service workforce and is the largest piece of this functional category.

b. *Other Than Full-Time Permanent Positions:* This category includes the salaries of NASA's non-permanent workforce. Programs such as students participating in cooperative training, summer employment, youth opportunity, and temporary clerical support are covered in that category.

c. *Reimbursable Detailees:* In accordance with existing agreements, NASA reimburses the parent Federal organization for the salaries and related costs of persons detailed to NASA.

d. *Overtime and Other Compensation:* Overtime, holiday, post and night differential, and hazardous duty pay are included in this category. Also included are incentive awards for outstanding achievements and superior performance.

2. *Benefits.*—In addition to compensation, NASA, as authorized and required by law, makes the employer's contribution to personnel benefits. These benefits include contributions to the Civil Service Retirement Fund, the Federal Employees Retirement System, employees' life and health insurance, payments to the Medicare fund for permanent employees, and social security contributions for non-permanent personnel. Payments to the civil service retirement fund for re-employed annuitants and for severance pay to former employees involuntarily separated through no fault of their own are also included.

B. SUPPORTING COSTS

1. *Transfer of Personnel.*—Provided under this category are relocation costs required by law, such as the expenses of selling and buying a home, and the movement and storage of household goods.

2. *Office of Personnel Management Services.*—The Office of Personnel Management is reimbursed for activities such as security investigations on new hires, recruitment advertising, and career-maturity surveys.

3. *Personnel Training.*—Training is provided within the framework of the Government Employees Training Act of 1958. Part of the training costs of courses offered by other Government agencies, and the remainder provides for training through nongovernment sources.

II. TRAVEL

A. PROGRAM TRAVEL

The largest part of travel is for direction, coordination and management of program activities including international programs and activities. The complexity of the programs and the geographical distribution of NASA installations and contractors necessitate the need for this category of travel. As projects reach the flight stage, support is required for prelaunch activities, including overseas travel to launch and tracking sites. The amount of travel required for flight projects is significant as it is directly related to the number of systems and subsystems, the number of design reviews, and the number and complexity of the launches and associated ground operations.

B. SCIENTIFIC AND TECHNICAL DEVELOPMENT TRAVEL

Travel to scientific and technical meetings and seminars permits employees engaged in research and development to participate in both Government sponsored and nongovernment sponsored activities. This participation allows personnel to benefit from exposure to technological advances which arise outside NASA, as well as allowing personnel to present both accomplishments and problems to their associates and provides for the dissemination of technical results to the United States community. Many of the Government sponsored meetings are working panels convened to solve certain problems for the benefit of the Government.

C. MANAGEMENT AND OPERATIONS TRAVEL

Management and operations travel provides for the direction and coordination of general management matters and travel by officials to review the status of programs. It includes travel by functional managers in such areas as personnel, financial management and procurement. This category also includes the cost of travel in and around the Installations; travel of unpaid members of research advisory committees; and initial duty station, permanent change of assignment, and other family travel expenses. Payments to inter-agency motor pools are included in the Operation of Installation function (Management and Operations subfunction).

III. OPERATION OF INSTALLATION

Operation of Installation provides a broad range of services, supplies, and equipment in support of the centers' institutional activities. These are divided into three major subfunctional areas: Facilities Services (the cost of renting real property, maintaining and repairing institutional facilities and equipment, and the cost of custodial services and utilities); Technical Services (the cost of automatic data processing for management activities, and the cost of educational and information programs and technical shops supporting institutional activities); and Management and Operations (the cost of administrative communications, printing, transportation, medical, supply, and related services). The content of the following subfunctions has been adjusted to reflect the realignment of the R&PM appropriation. A description of each major subfunction follows:

A. FACILITIES SERVICES

1. Rental of real property.—Rental of real property includes the rental of building space directly by NASA or through the General Services Administration to meet offsite office, warehousing, and other requirements which cannot otherwise be provided in existing buildings at the NASA Installation. Most of the funding is required for rental of the NASA Headquarters complex of buildings in the District of Columbia, and nearby Maryland and Virginia that are either Government-owned or leased. NASA must provide rental payments to the General Services Administration in accordance with P.L. 92-313 for these facilities.

2. Maintenance and related activities.—Maintenance and related activities include the recurring day-to-day maintenance of facilities (grounds, buildings, structures, etc.) and equipment accomplished by non-Civil Service personnel. This involves the mowing and care of grassy areas, care of trees and shrubs, elevators, cranes, pressure vessel inspections, painting and protective coatings, general buildings maintenance, and the maintenance of installed mechanical, electrical, and other systems. In addition, this item includes feasibility studies, project design, construction supervision, inspection, and other institutional facility engineering functions. Included also are any applicable costs associated with recurring facility work as

well as materials, hardware, and equipment used in facility maintenance activities, whether accomplished by civil service personnel or contractors. In the cost of equipment, related maintenance and other services are reflected for office, shop, laboratory and other facilities equipment as well as administrative internal communications and television monitoring equipment.

3. *Custodial services.*—Custodial services include janitorial and building cleaning services, pest control, fire protection services, security services including badging and identification, lock and safe repair, trash and refuse handling, window blinds and light fixture cleaning, and laundry and dry cleaning of facility related items.

4. *Utilities services.*—Utilities services include the purchase of utilities such as electricity, natural gas, fuel oil, coal, steam, propane, and other fuel commodities as well as water and sewage treatment services. Also included are the related maintenance and operating costs of the utility plants and systems.

B. TECHNICAL SERVICES

1. *Automatic data processing.*—

a. *Equipment.*—This category provides for the lease, purchase and maintenance of general purpose data processing equipment which supports institutional operations at each installation. Excluded is equipment dedicated to specific research or operational systems which is funded from the Research and Development or the Space Flight, Control and Data Communications appropriations.

b. *Operations.*—Operations services include programming, computer operations and related services for institutional applications including payroll, financial management, security, maintenance, personnel, logistics, and procurement records and reports.

2. *Scientific and technical information and educational programs.*—

a. *Libraries.*—The technical libraries are established to provide installation staff with books, periodicals, technical reports and other scientific documentation.

b. *Education and information programs.*—The educational and information programs provide for the documentation and dissemination of information about the Agency's programs to the general public, the educational community at the elementary and secondary levels, and the mass communications media. Assistance to the mass communications media includes the assembly and exposition of newsworthy material in support of requests in the form of press kits, news releases, television and radio information tapes and clips, and feature material.

c. *Support services.*—Support services include safety, and the production of general photographic services, graphics, and audio-visual materials.

C. MANAGEMENT AND OPERATIONS

1. *Administrative communications.*—Included in this category are costs not dedicated to a specific program or project, and cover

leased lines, long distance tolls (including FTS charges), teletype services, and local telephone service.

2. *Printing and reproduction.*—Included in this category are the costs for duplicating, blueprinting, microfilming, and other photographic reproductions. Also included in this category are Government Printing Office printing costs, contractual printing and the related composition and binding operations.

3. *Transportation.*—Transportation services include the operation and maintenance of all general purpose motor vehicles used by both civil service and support contractor personnel and the operation of the NASA administrative aircraft fleet. The cost of movement of supplies and equipment by commercial carriers and payments to interagency motor pools are also in this category.

4. *Installation common services.*—Installation common services include support activities at each installation such as: occupational medicine and environmental health; mail service; supply management; patent services; administrative equipment; office supplies and materials; and postage.

6/4/87

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[The following material was provided in response to questions submitted to National Aeronautics and Space Administration prior to the FY 1990 authorization hearings.]

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QUESTIONS SUBMITTED BY THE
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
ON NASA'S FY 1990/1991 BUDGET

1. Please furnish the following tabulation, by major program, for the FY 1990/1991 request:
 - a. The original recommended budget to OMB.
 - b. The adjustments made.
 - c. The submission to Congress.
 - d. Brief comment on the adjustments made, i.e., a description of corresponding program impacts or changes.
 - e. The comparative FY 1989 operating plan figure.
 - f. Please assign an agency priority to those programs requested from OMB, but not presented to Congress.

FY 1960-61
Jan 19, 1960NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1960 BUDGET SUMMARY
(Millions of Dollars)

	FY 1959 REQUEST	FY 1960 REQUEST	FY 1960 COMO REQUEST
RESEARCH AND DEVELOPMENT			
Space Station	4266.6	6176.5	5791.6
Space Transportation Capability Development	866.0	2136.2	2650.2
Space Station	661.0	677.0	639.0
Space Station	66.6	86.6	86.6
Upper Stages	138.0	166.7	166.7
Engineering & Technical Data	155.4	201.0	189.0
Payload Operations & Support Equipment	64.7	84.8	81.1
Advanced Programs	52.7	48.7	48.7
Tethered Satellite System	20.4	18.6	19.9
Orbital Maneuvering Vehicle	72.0	107.0	107.0
Advanced Launch System	41.4	16.0	5.0
Space Science & Applications	1820.2	2136.2	1985.3
Physics and Astronomy	726.1	946.1	884.5
Robotic Space Telescope Development	95.0	87.0	87.0
Remote Day Observatory Development	41.0	26.7	26.7
Advanced X-Ray Astrophysics Facility	10.0	64.0	64.0
Global Neutron Telescope	64.4	112.3	112.3
Payload & Instrument Development	81.7	116.3	71.0
Shuttle/Spacecraft Payload Mission Management & Integration	68.7	95.0	68.1
Space Station Integrated Planning & Attached Payloads	0.0	23.0	23.0
Explorer Development	42.1	93.2	93.2
Mission Operations & Data Analysis	162.2	204.8	204.8
Research & Analysis	85.0	112.5	112.5
Suborbital Program	65.4	52.5	52.5
Life Sciences	70.1	124.2	124.2
Human Space Flight & Systems Engineering	27.6	42.0	42.0
Space Biological Sciences	10.1	27.6	27.6
Research & Analysis	48.4	52.6	52.6
Planetary Exploration	416.6	486.9	386.0
Orbiter Development	72.4	17.4	17.4
Physician Development	16.3	14.5	14.5
Biological Development	45.1	14.5	14.5
Earth Observer	102.2	100.5	100.5
Comet Rendezvous Interplanetary/Cometary	110.7	48.8	30.0
Mission Operations & Data Analysis	76.9	133.4	133.4
Research & Analysis	76.9	79.1	79.1

Comments: at FY 1960 general reduction -500

Delete ACTS upper stage -6000000 100 and 116 -120
General reduction
Communications (or Reeling Module)

Cancel RP-B -250/CRS CLV Rm -120/geo p/l opt -50

Delete institutional lab equip

General reduction

FT 1980	REQUIRE	△	REQUIRE
Space Applications	601.4	-76.3	525.1
Earth Sciences	613.7	-10.0	603.7
Upper Atmosphere Research Satellite	94.2	0.0	94.2
Space Topography Experiment	82.0	0.0	82.0
Scatterometer	18.6	0.0	18.6
Earth Probe	10.0	-10.0	0.0
Earth Resources Payload Instrument Development	64.4	64.5	0.1
Airborne Science & Applications	23.0	19.7	3.3
Geodynamics	32.9	30.0	2.9
Mission Operations & Data Analysis	17.6	24.0	6.4
Research & Analysis	100.0	124.0	24.0
Materials Processing	75.0	92.7	17.7
Space Communications	92.2	84.9	7.3
Information Systems	19.9	34.1	14.2
Commercial Programs	44.7	67.0	22.3
Technology Utilization	16.5	26.7	10.2
Commercial Use of Space	28.2	40.3	12.1
Aeronautical Research & Technology	404.2	512.0	107.8
Research & Technology Base	315.6	340.7	25.1
System Technology Programs	49.6	164.1	114.5
Advanced Propulsion Systems Technology	(19.2)	(20.2)	(1.0)
Advanced Materials Technology	(4.0)	(16.9)	(12.9)
High-Performance Aircraft	(11.0)	(20.9)	(9.9)
Systems Technology	(12.9)	(21.3)	(8.4)
Advanced Propulsion Systems Technology	(59.7)	(62.3)	(2.6)
Memorial Aerodynamic Simulation	203.9	637.2	433.3
Space Research & Technology	134.1	100.2	-33.9
Research & Technology Base	121.8	(31.4)	(-90.6)
Civil Space Technology Initiative	(13.3)	(29.0)	(15.7)
Space Station	(13.3)	(17.3)	(4.0)
Information Technology	(19.3)	(22.9)	(3.6)
Large Structures & Control	(11.1)	(11.1)	(0.0)
Power	(23.9)	(26.0)	(2.1)
Automation & Robotics	60.0	97.5	37.5
Pathfinder Program	(4.0)	(10.0)	(6.0)
Surface Exploration	(15.0)	(27.0)	(12.0)
In-Space Operations	(4.0)	(14.0)	(10.0)
Human Factors	(3.3)	(12.0)	(8.7)
Space Transfer	(3.0)	(23.0)	(20.0)
Orbital Studies	69.4	127.0	57.6
In-Space Flight Experiments	30.0	-12.0	42.0
Translunar/Planetary Research & Technology	127.0	0.0	127.0

Relate TMS instrument

Terrestrial ACIS

Relate BTIC
Relate CDS aug

High computing exp -100/20000-150

Tilting aug

Ultra High Speed (Subsonic)

Relate Institutional Lab Equip Aug

Slow build-up

Slow build-up

General program reduction

	FY 1980 REQ	FY 1980 CONG REQUEST	FY 1980 REQ Δ	
Science, Reliability & Quality Assurance	22.4	22.3	-10.0	General program reduction
University Space Science & Technology Academic Program	(22.3)	37.0	-2.0	General program reduction
Training & Data Advanced Systems	10.0	19.0	0.0	19.0
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	4464.2	3342.7	-482.1	5139.6
Shuttle Production & Capability Development	1128.2	1470.6	-119.3	1305.3
Orbiter Operational Capability	201.0	321.7	-84.7	237.0
Propulsion Systems	502.2	753.0	-24.5	727.3
Launch & Mission Support	245.2	349.1	-8.1	341.0
Space Shuttle Operations	2305.2	2400.0	-42.7	2357.7
Flight Operations	689.7	777.0	-5.0	772.0
Flight Hardware	1117.7	1266.2	-29.7	1236.5
Launch & Landing Operations	506.0	562.0	-9.0	553.0
Expendable Launch Vehicles	65.5	298.8	-120.5	109.5
Space & Ground Networks, Communications & Data Systems	945.3	1212.7	-111.6	1102.1
Space Network	402.0	631.3	-49.0	582.3
Ground Network	220.1	296.7	-27.1	269.6
Communications & Data Systems	223.2	285.7	-15.5	270.2
CONSTRUCTION OF FACILITIES	275.1	500.0	-160.1	341.0
RESEARCH & PROGRAM MANAGEMENT	1001.0	2141.0	-100.0	2042.2
INSPECTION GENERAL	(0.0)	0.0	0.0	0.0
TOTAL	10097.5	14381.7	-1107.7	13274.0

Delay structural spares -50M, Communications 100 -27M,
Reduce change allowance -42M

Cancel/defer flight to FY 90 & 91

Cancel Planetary Backup

1980 Replacement -25M/1000 -25M/400 1980 -40M/400 800 -13M
USN 2-Head Split -10M/Station Estimates -4M/800 800 -10M
COS 9-phase -10M/Space Data Processing Data Deliveries -4M
Comorbidity/ASB -40M, NOL -20M, Space Station Prep Fee -42M,
Observational Test Lab -10M, general reduction -21M
Absorb pay raise & health benefits (50M), delete augmentations
and reduce level of support

2. Please furnish the following information, by NASA Center and by major program, for the FY 1990/1991 budget request:

- a. Original Center request to NASA Headquarters.
- b. The adjustment made.
- c. Brief comments on adjustments made.
- d. The submission to Congress as allocated by Center.
- e. The comparative FY 1989 operating plan figure, by Center.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1990 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

	HEADQUARTERS (Billions of Dollars)			FY 1990 BUDGET REQUEST	REMARKS
	FY 1989 CURRENT ESTIMATE	FY 1990 CENTER REQUEST			
SPACE STATION	151.1	216.8	-3.6	219.2	REDUCTIONS DUE TO SLIP IN R&D, CAP AND DISCREED DELIVERIES OFFSET BY INCREASES IN AGENCY SUPPORT, TECHNOLOGY EFFORTS.
STS CAPABILITY DEVELOPMENT	60.9	70.7	-16.2	62.5	REDUCE PROPOSED ALE CIVIL STUNT EFFORTS
SHUTTLE PROGRAM & OPS CAPABILITY	20.0	87.4	-26.2	61.1	COMMERCIALIZE END
STS OPERATIONS	36.2	64.7	-3.7	59.6	GENERAL PROGRAM REDUCTION
PHYSICS AND ASTRONOMY	74.7	88.5	0.0	88.5	
LIFE SCIENCES	13.6	18.6	0.0	18.6	
PLANETARY EXPLORATION	67.9	47.5	0.0	47.5	
SPACE APPLICATIONS	52.6	37.1	0.0	37.1	
TECHNOLOGY UTILIZATION	10.4	12.7	1.1	13.8	FUNDING FOR ADAMT
COMMERCIAL USE OF SPACE	19.3	16.6	6.2	25.6	CCOS ADVERTISEMENT, ADDITIONAL BOUNDING BUDGET EFFORT
RESEARCH	0.4	12.0	-6.0	6.0	REDUCTIONS IN DATA SYSTEMS INTEGRATION, TENDING ANALYSIS AND SIGNIF- ICANT PROBLEM REPORTING SYSTEM
AERONAUTICAL RESEARCH & TECHNOLOGY	9.2	12.0	-2.6	16.0	REDUCTION IN HIGH PERFORMANCE COMBUSTION INITIATIVE
SPACE RESEARCH AND TECHNOLOGY	37.3	77.9	-60.8	37.1	DELETION OF UNIVERSITY SPACE ENGINEERING ADVERTISEMENT, REDUCTIONS IN PATRIOTIC AND IN-SPACE EXPERIMENTS TECHNOLOGY
TRANSATMOSPHERIC RESEARCH & TECHNOLOGY	50.0	109.3	-2.3	107.0	REDUCTION CONSISTENT WITH MOW
SPACE & NETWORK COMMUNICATION & DATA SYS	257.9	260.7	0.0	260.7	
WINDY SPACE SCIENCE & TECH ACADEMIC PROG	(11.8)	21.2	-2.9	18.3	GENERAL PROGRAM REDUCTION
TOTAL	850.0	1180.9	-99.1	1087.8	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1960 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

JOHNSON SPACE CENTER
(Millions of Dollars)

	FY 1960 CURRENT ESTIMATE	FY 1960 CENTER REQUEST	FY 1960 BUDGET REQUEST	REMARKS
SPACE STATION	32.0	1116.0	-230.9	WORK PACKAGE ACTIVITIES DECREASED DUE TO SLIP IN PPO, CPO, HARDWARE DELIVERIES, PPO PRIVATIZATION INITIATIVE
STC CAPABILITY DEVELOPMENT	145.4	287.2	-167.1	DELAY ROCKING BOMBLE AND REPAIR TRAINING/OPERATIONS FACILITY FOR OMV, REDUCE REQUESTED STN AUGMENTATION AND INCREASE ADVANCED PROGRAMS CAPABILITY
SHUTTLE PROGRAM & OMV CAPABILITY	338.5	737.3	-340.1	DELETE ORBITER OV-104, DELAY STRUCTURAL SPARES, COMMERCIALIZE EDO, REDUCE CHANGE ACTIVITY FOR OBSOLESCENCE AND MODIFICATIONS
STN OPERATIONS	655.4	629.7	-90.2	REDUCE CENTER REQUEST FOR INCREASE TO STGOC CONTRACTOR OFFSET PARTIALLY BY ADDING FUNDS AS THE RESULT OF LOSS OF 600 REIMBURSEMENTS FOR SECURE OPERATIONS
PHYSICS AND ASTRONOMY	13.0	16.9	0.1	
LIFE SCIENCES	20.7	53.6	-5.0	REDUCED INCREASE FOR SPACE BIOLOGY INITIATIVE AND EXTENDED CREW OPS, REDUCED SPACEPLAN SUPPORT DUE TO FY 1960 CONGRESSIONAL REDUCTION
PLANETARY EXPLORATION	9.3	9.1	0.0	
SPACE APPLICATIONS	2.9	3.7	0.0	
COMMERCIAL USE OF SPACE	2.5	1.7	0.0	
TECHNOLOGY UTILIZATION	0.5	0.3	0.6	
SEASON	2.6	4.0	-1.5	ADDITIONAL FUNDING FOR ADANET
SPACE RESEARCH AND TECHNOLOGY	14.0	38.1	-22.0	REDUCTIONS IN SOFTWARE ASSURANCE METHODOLOGIES
UNIV SPACE SCIENCE & TECH ACADEMIC PROG	(1.1)	2.4	0.0	REDUCTIONS IN PAYMASTER, EQUIPMENT, AND IN-SPACE EXPERIMENTS TECHNOLOGY AUGMENTATION
TOTAL	1563.0	3100.9	-813.9	2287.0

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1969 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION
MARSHALL SPACE FLIGHT CENTER
(Millions of Dollars)

	FY 1969 CURRENT ESTIMATE	FY 1969 CENTER REQUEST	FY 1969 BUDGET REQUEST	REMARKS
SPACE STATION	161.3	461.5	-29.2	WORK PACKAGE ACTIVITIES DEPRIVED DUE TO SLIP IN PDB, CDB AND BAWHARE DELIVERIES
STS CAPABILITY DEVELOPMENT	375.0	382.8	-67.9	REPHASE 1965-6 ISS DELIVERY DATE, SELECT STATIONING FOR RIT FOR PLANETARY BACKUP, DELAY AND FOR PROGRAM REASSESSMENT, DEFER DECISION ON LUNAR LUNAR ROCKET PHASE 3 STUDIES
SHUTTLE PDB & OPS CAPABILITY	561.1	956.6	-228.7	REPHASE FUNDING FOR AIRM CONSISTENT WITH DELAY IN PROGRAMMENT ACTIVITIES, DELAY PHASE 2 & SOME DEVELOPMENT PLAN TWO YEARS
STS OPERATIONS	948.7	1185.3	-122.3	REPHASE AND DEFER OPS REQUIREMENTS CONSISTENT WITH REDUCING FLIGHT MODEL THROUGH FY 1964 AT 3 FLIGHTS, IMPROVE PROJECTED TURNAROUND TIME FOR REUSABLE BAWHARE AT ESC
PHYSICS AND ASTRONOMY	282.3	178.0	10.9	INCREASE FOR MARBLE SPACE TELESCOPE LAUNCH DELAY OFFSET BY REDUCED ALAP DEVELOPMENT, GRAVITY PROBE-B DELAY
LIFE SCIENCES	0.1	0.1	0.0	0.1
PLANETARY EXPLORATION	0.1	0.2	0.0	0.2
SPACE APPLICATIONS	37.2	44.1	-3.9	0.2
COMMERCIAL USE OF SPACE	1.0	15.6	-13.7	1.0
TECHNOLOGY UTILIZATION	0.2	0.9	-0.2	0.7
16406	1.0	1.8	0.8	1.8
ASTRONAUTICAL RESEARCH & TECHNOLOGY	1.0	3.9	0.0	3.9
SPACE RESEARCH AND TECHNOLOGY	40.1	98.4	-22.4	86.0
SPACE & NETWORK COMMUNICATION & DATA SYS	40.0	54.5	-4.7	40.8
ONLY SPACE SCIENCE & TECH ACADEMIC PDB	(2.2)	2.7	0.0	2.7
TOTAL	2481.7	3336.4	-568.1	2768.3
	*****	*****	*****	*****

REDUCTIONS IN CSTI, PATTERFINDER, EQUIPMENT, IN-SPACE EXPERIMENT TECHNOLOGY AUGMENTATION

REDUCED FUNDING FOR PROGRAM SUPPORT COMMUNICATIONS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1969 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

KENNEDY SPACE CENTER
(Millions of Dollars)

	FY 1969 CURRENT ESTIMATE	FY 1969 CENTER REQUEST	FY 1969 BUDGET REQUEST	REMARKS
SPACE STATION	21.4	92.2	77.4	ACTIVITIES DECREASED DUE TO SLIP IN P80 AND C80 SUPPORT ACTIVITIES, SLIP IN MAINTENANCE DELIVERIES TO SSC
STS CAPABILITY DEVELOPMENT	78.4	97.5	88.8	DECREASE SPACEFLIGHT MAINTENANCE COSTS THROUGH IMPLEMENTING REPORT TRANSMISSION AND PARTIAL INCREASE IN STS80 SUPPORT MAINTENANCE
SHUTTLE PROGRAM CAPABILITY	144.6	157.0	128.8	DELICATE PROPOSED IMPROVEMENTS TO ADDRESS SUPPORT CHANGES, DEFER CONTINGENT REPLACEMENTS/IMPROVEMENTS
STS OPERATIONS	636.8	688.5	742.6	DECREASE MAINTENANCE THIS FISCAL YEAR, INCREASE PAYLOAD SUPPORT, DECREASE SUPPORT TO LOWER FLIGHT RATE
PHYSICS AND ASTRONOMY	0.0	11.6	11.6	
LIFE SCIENCES	2.1	3.0	3.0	
COMMERCIAL USE OF SPACE	0.3	0.7	0.7	
TECHNOLOGY UTILIZATION	0.7	0.7	0.7	
SPACE RESEARCH AND TECHNOLOGY	1.8	5.0	0.7	REDUCTION IN PAYLOADS AND EQUIPMENT
DESIGN	0.3	0.3	0.3	
ONLY SPACE SCIENCE & TECH SCENARIO PROGRAM	(6.5)	1.0	1.0	
TOTAL	914.8	1171.6	1056.1	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION				
FY 1960 BUDGET REQUEST				
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION				
JET PROPULSION LABORATORY				
(Millions of Dollars)				
	FY 1960 CURRENT ESTIMATE	FY 1960 CENTER REQUEST	FY 1960 BUDGET REQUEST	REMARKS
SPACE STATION	9.9	11.9	12.4	25.3
STS CAPABILITY DEVELOPMENT	4.8	1.5	-0.3	1.2
SHUTTLE PROGRAM & STS CAPABILITY	1.8	1.8	0.0	1.8
PHYSICS AND ASTRONOMY	18.4	18.0	0.0	18.0
LIFE SCIENCES	1.1	2.3	0.0	2.3
PLANETARY EXPLORATION	226.3	317.6	-0.6	309.0
SPACE APPLICATIONS	140.6	166.2	-0.2	159.0
TECHNOLOGY UTILIZATION	1.0	1.1	0.0	1.1
AERONAUTICAL RESEARCH & TECHNOLOGY	0.3	4.8	-4.5	0.3
SPACE RESEARCH AND TECHNOLOGY	40.3	75.6	-26.2	49.4
SR&RA	2.0	4.5	-1.8	3.5
SPACE & NETWORK COMMUNICATION & DATA STS	138.0	163.7	6.6	176.3
UNIV SPACE SCIENCE & TECH ACADEMIC PROG	(1.1)	1.0	0.0	1.0
				PRIMARYLY SPACE ORBITAL DEBRIS RADAR
				INCREASE FOR MARS BALLOON RELAY OFFSET BY REDUCTION IN CLAF
				REDUCTION IN SCATTERMETER OFFSET BY INCREASE IN TOPOL
				REDUCTION IN HIGH-PERFORMANCE COMPUTING INITIATIVE
				REDUCTIONS IN PALFINDER, CSTI, EQUIPMENT, IN-SPACE EXPERIMENT TECHNOLOGY DEMONSTRATION
				ADVANCED PARTS TECHNOLOGY PROGRAM NOT APPROVED
				INCREASE FOR VARIOUS DSM SYSTEM UPGRADES DEFERRED FROM FY 1960

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
 FY 1980 BUDGET REQUEST
 RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

GOVERNMENT SPACE FLIGHT CENTER
 (Millions of Dollars)

	FY 1980 CURRENT ESTIMATE	FY 1980 CENTER REQUEST	FY 1980 BUDGET REQUEST	REMARKS
SPACE STATION	100.7	286.0	-109.2	REDUCTION IN FY80 PROGRAM REVIEW AND INITIALIZATION, REPLACING OF WORK PACKAGE ACTIVITIES DUE TO SLIP IN PMR, CDR AND SHUTTLE DELIVERIES
STS CAPABILITY DEVELOPMENT	7.0	10.0	-3.0	REDUCE PROPOSED ADVANCED PROGRAMS PROJECTS
SHUTTLE PROGRAM & OPS CAPABILITY	0.0	0.0	0.0	
STS OPERATIONS	55.0	147.5	-60.5	DEPHASE OPS LAUNCH DATES AND ADJUST SMALL LAUNCH VEHICLES TO UTILIZE REGIONAL WAREHOUSE FROM THE 90s
PHYSICS AND ASTRONOMY	401.0	610.1	-20.0	DEFER HUBBLE SPACE TELESCOPE OPS, END LAUNCH SLIP, ONE REDUCTIONS, HUBBLE FUNDING REPROGRAMMED TO YETTER-1 WORK AT WSCF
LIFE SCIENCES	0.2	0.2	0.1	
PLANETARY EXPLORATION	17.0	23.5	-6.0	SUBSTITUTION OF INSTRUMENTS ON MARS OBSERVER SPACECRAFT
SPACE APPLICATIONS	220.5	246.2	-5.1	DEFER ORAS ACTIVITIES
COMMERCIAL USE OF SPACE	0.1	1.1	-0.0	
TECHNOLOGY UTILIZATION	1.0	1.0	0.1	
ALTERNATIVE RESEARCH & TECHNOLOGY	0.2	5.7	-5.5	REDUCTION IN HIGH PERFORMANCE COMPUTING ARGUMENTATION
SPACE RESEARCH AND TECHNOLOGY	7.5	20.5	-10.7	REDUCTIONS IN PAYLOADS, COST, EQUIPMENT, IN-SPACE EXPERIMENTS TECHNOLOGY ARGUMENTATION
BREDA	1.5	1.0	0.0	
SPACE & NETWORK COMMUNICATION & DATA SYS	510.4	704.9	-27.7	REPHRASING OF STOT, TARS REPLACEMENT, WEST SYSTEM REPLACEMENT, AND SPACE STATION SUPPORT, REDUCED LEVEL OF FUNDING FOR SPACE NETWORK, COMMUNICATIONS AND DATA SYSTEMS
UNIV SPACE SCIENCE & TECH ACADEMIC PROG	11.53	2.1	0.0	
TOTAL	1224.3	2040.9	-337.9	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1980 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION
AMES RESEARCH CENTER
(Millions of Dollars)

	FY 1980 CURRENT ESTIMATE	FY 1980 CENTER REQUEST	FY 1980 BUDGET REQUEST	REMARKS
SPACE INITIATION	2.9	7.0	5.8	
STS CAPABILITY DEVELOPMENT	0.0	0.9	0.0	CENTER ALLOCATION APPROVAL DEFERRED PENDING REQUIREMENTS DEFINITION, FUNDING REQUESTED FOR STS PRIVATIZATION INITIATIVE
STS OPERATIONS	6.0	6.5	6.5	DELETE PROPOSED SATELLITE SERVICING PROJECT
PHYSICS AND ASTRONOMY	15.0	25.9	25.0	
LIFE SCIENCES	20.7	54.7	50.7	DELAY IN LENSITRINE AND OHP, DEFERRED SPACELAB EXPERIMENTS BASED ON FY 1980 CONGRESSIONAL REDUCTION
PLANETARY EXPLORATION	15.1	15.7	13.7	GENERAL REDUCTION
SPACE APPLICATIONS	25.3	20.5	26.3	WORK TO DC-8 COMPLETED IN FY 1980
COMMERCIAL USE OF SPACE	0.4	0.6	0.6	
TECHNOLOGY UTILIZATION	0.5	0.4	0.4	
AERONAUTICAL RESEARCH & TECHNOLOGY	155.4	161.2	160.2	ACCELERATIONS DELETED IN SUBSONIC TRANSPORT TECHN, TILTING/COMMITTEE TECHNOLOGY, DEFERRED FUNDING FOR HIGH PERFORMANCE COMPUTING AND HIGH PERFORMANCE AIRCRAFT AUGMENTATIONS
SPACE RESEARCH AND TECHNOLOGY	32.0	46.6	33.4	DECREASES IN ROTUNDS, CSTI, EQUIPMENT, IN-SPACE EXPERIMENTS TECHNOLOGY MATURATION
TRANSATMOSPHERIC RESEARCH & TECHNOLOGY	4.6	5.3	5.0	REDUCTION IN TECHNOLOGY MATURATION EFFORT
SR&A	0.5	0.5	0.5	
SPACE & NETWORK COMMUNICATION & DATA STS	11.2	12.3	11.0	
UNIV SPACE SCIENCE TECH ACAD/ENR PROG	1.0	1.2	1.2	INCREASED FUNDING FOR AERONAUTICS TRACELING OPS SUPPORT
TOTAL	200.3	205.7	252.4	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1990 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

(MILLIONS OF DOLLARS)

	FY 1990 CURRENT ESTIMATE	FY 1990 CENTER REQUEST	FY 1990 BUDGET REQUEST	REMARKS
SPACE STATION	2.0	4.3	-0.3	CENTER ALLOCATION REFERRED PENDING DEFINITION OF REQUIREMENTS
STS CAPABILITY DEVELOPMENT	1.4	1.4	-0.1	ADD SATELLITE SERVICING TASKS
STS OPERATIONS	0.0	20.7	-12.7	ADJUST SMALL LAUNCH VEHICLES TO UTILIZE REGIONAL ORB HARDWARE
LIFE SCIENCES	0.5	0.5	-0.0	INCREASED IN LIBAR AND ORION RESEARCH
SPACE APPLICATIONS	22.5	22.0	1.2	ADDITIONAL NEW APPLICATIONS PROJECTS
COMMERCIAL USE OF SPACE	0.0	0.7	0.4	REDUCTIONS IN RIM-SPEED RESEARCH, RIM PERFORMANCE COMPUTING AND AIRCRAFT TECHNOLOGY ASSOCIATIONS, SELECTION OF AERONAUTIC TRANSPORT TECHNOLOGY, TILTYOUTHCOMMITTED TECHNOLOGY ADMINISTRATION
TECHNOLOGY UTILIZATION	0.7	0.3	1.1	DECREASED IN PATENTED, CFTI, EQUIPMENT, IN-SPACE EXPERIMENTS TECHNOLOGY ADMINISTRATION
AERONAUTICAL RESEARCH & TECHNOLOGY	102.0	205.2	-10.2	REDUCTIONS IN TECHNOLOGY MATURATION EFFORT
SPACE RESEARCH AND TECHNOLOGY	50.5	70.1	-19.4	ELECTRONIC PACKAGING PROGRAM NOT APPROVED
TRANSATMOSPHERIC RESEARCH & TECHNOLOGY	0.0	24.4	-15.4	
RESEARCH	3.2	5.3	-1.5	
UNIV SPACE SCIENCE & TECH ACADEMIC PROG	12.2	3.5	0.0	
TOTAL	244.0	367.2	-87.1	
	*****	*****	*****	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1990 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, CONTROL AND DATA COMMUNICATION

LEADS RESEARCH CENTER
(Millions of Dollars)

	FY 1989 CURRENT ESTIMATE	FY 1990 CENTER REQUEST	FY 1990 BUDGET REQUEST	REMARKS
SPACE STATION	131.8	348.4	381.8	UNDER PACKAGE ACTIVITIES DECREASED DUE TO SLIP IN CDR, PDR AND HARDWARE DELIVERIES
STS CAPABILITY DEVELOPMENT	2.2	1.8	1.8	
ORBITAL PDR & OPS CAPABILITY	3.4	18.6	2.3	REDUCE HOME BIOMONITORING PROGRAM
STS OPERATIONS	26.4	237.4	31.8	UNDER 1989-F AND -B FROM TITAN TO STS LAUNCHES, CANCEL PLANETARY BACKUP DUE TO TITAN AVAILABILITY
PROBES AND ASTEROIDS	8.1	8.5	8.3	
SPACE APPLICATIONS	99.9	94.9	38.9	SELECTION OF FUNDS FOR ACTS PROGRAM
COMMERCIAL USE OF SPACE	0.4	1.2	1.8	
TECHNOLOGY UTILIZATION	8.5	8.3	8.6	
AERONAUTICAL RESEARCH & TECHNOLOGY	94.9	188.5	116.2	REDUCTIONS IN HIGH-SPEED RESEARCH, HIGH PERFORMANCE AIRCRAFT TECHNOLOGY ACQUISITION, SELECTION OF AERONAUTIC TRANSPORT, TITAN/PRO/COMMITTED TECHNOLOGY ACQUISITIONS
SPACE RESEARCH AND TECHNOLOGY	64.4	181.1	66.6	DECREASED IN PATTERNS, COST, EQUIPMENT, IN-SPACE TECHNOLOGY ACQUISITION
TRANSATMOSPHERIC RESEARCH & TECHNOLOGY	0.1	10.4	0.6	
SR&A	1.5	2.8	2.8	
WVW SPACE SCIENCE & TECH ACADEMIC PROGRAM	11.81	1.2	1.2	REDUCTION IN TECHNOLOGY ACQUISITION EFFORT
TOTAL	617.1	948.3	581.1	

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1960 BUDGET REQUEST
RESEARCH AND DEVELOPMENT/SPACE FLIGHT, COMBUSTION AND DATA COMMUNICATION

STEMMING SPACE TECHNOLOGY LABORATORIES
(Billions of Dollars)

	FY 1960 CURRENT ESTIMATE	FY 1960 CENTER REQUEST	FY 1960 BUDGET REQUEST	REMARKS
SPACE STATION	0.1	3.4	-3.3	0.1
STS CAPABILITY DEVELOPMENT	5.7	5.0	0.1	3.0
SHUTTLE PROGRAM & STS CAPABILITY	17.0	21.2	-5.2	16.0
SHUTTLE OPERATIONS	2.1	2.4	0.0	2.4
LIFE SCIENCES	0.1	0.1	0.0	0.1
SPACE APPLICATIONS	0.5	0.5	0.0	0.5
COMMERCIAL USE OF SPACE	2.0	2.7	2.0	5.5
TECHNOLOGY UTILIZATION	1.1	0.9	0.3	1.2
UNIV SPACE SCIENCE & TECH ACADEMIC PROGRAM	10.31	0.0	0.0	0.0
TOTAL	36.1	36.9	-7.4	32.3

CENTER APPROVAL DEFERRED PERFORMING REQUIREMENTS DEFINITION

DELETE REQUESTED ADDITIONAL HYDROGEN BARGE

SUPPORT OF REMOTE SENSING ACTIVITIES

- ✓3. Please furnish by major line item, the NASA operating plan for FY 1989 with comments on adjustments, if any.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FY 1988 AND FY 1989 OPERATING PLANS
BY BUDGET LINE ITEM
(Dollars in Millions)

	FY 1988	FY 1989
RESEARCH & DEVELOPMENT	3254.9	4266.6
Space Station	392.3	900.0
Space Transportation Capability Dev	593.4	681.0
Physics & Astronomy	614.4	734.1
Life Sciences	72.2	78.1
Planetary Exploration	327.7	416.6
Space Applications	567.5	601.4
Technology Utilization	19.0	16.5
Commercial Use of Space	29.7	28.2
Aeronautical Research & Technology	332.9	404.2
Space Research & Technology	221.3	295.9
Transatmospheric Research & Technology	52.6	69.4
Safety, Reliability & Quality Assurance	14.1	22.4
Tracking & Data Advanced Systems	17.9	18.8
SPACE FLIGHT, CONTROL, & DATA COMMUNICATIONS	3805.7	4484.2
Shuttle Production & Capability Development	1092.7	1128.2
Shuttle Operations	1833.6	2390.7
Space and Ground Networks, Communications & Data Systems	879.4	945.3
RESEARCH & PROGRAM MANAGEMENT	1762.2	1891.6
CONSTRUCTION OF FACILITIES	178.3	275.1
TOTAL NASA	9001.1	10897.5

4. Please provide the following tabulations of projected total cost for all major programs. The estimate should include the Project Operation Plan (POP) and the Program level costs (including reserves, management overhead, etc.).
- a. Original estimate date and amount.
 - b. Current estimate.
 - c. NASA's estimate of what portion of any increased cost may be due to inflation.

1990 CONGRESSIONAL BUDGET
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
ESTIMATED TOTAL PROJECT COST
(in millions of dollars)

	Original Development Estimate Date Range	Current Estimate
CRAF/Cassini	1/89 1500-1750(b)	1500-1750
Advanced X-ray Astrophysics Facility (AXAF)	1/88 1540-1700(b)	1620-1800
Global Geospace Science Mission	1/87 390-440	415-465(e)
Ocean Topography Experiment	1/86 380-430	380-430
Hubble Space Telescope Development	2/78 595-643(a)	1500-1600
Ulysses Development	1/83 120-140	160-180
Gamma Ray Observatory (GRO) Development	1/83 395-435	500-540
Galileo Development	1/83 650-700	890-920
Magellan Mission Development	1/83 320-350	460-470(f)
Tethered Satellite	1/83 40-50	105-125(c)
Upper Atmosphere Research Satellite (UARS)	1/84 630-700	730-780
Mars Observer	1/84 300-375	450-500
Scatterometer	1/84 120-135	TBD(g)
Orbital Maneuvering Vehicle	1/85 540-575	670-720(d)

- (a) Original Space Telescope estimate, which supported a late 1983 launch, was stated in FY 1978 budget dollars, to be updated annually; this estimate has been updated to reflect real year dollars. The increase reflected by the current estimate is due to continuing development problems and a series of launch slips from late 1983 to December 1989.
- (b) Planning estimate; development estimate not yet available.
- (c) The original Tether estimate for the employer development including program integration with the Italians was based on an April 1987 launch. The current range of \$105-125 million is based on a launch in January 1991. The major increase in the program cost estimate is the result of launch slippages caused by the Challenger accident and the associated increased emphasis on systems safety and reliability.
- (d) This estimate has been increased as a result of delaying the initial operational capability from 1990 to 1994. The delay in capability is consistent with deferral of the initial operational requirement in support of the Space Station.
- (e) The current range has been increased due to a FY 1989 funding reduction resulting in a 6-month launch delay for the two spacecraft.
- (f) An increase in the range is due to technical problems involving defective electronic parts and additional testing leading to the early 1989 launch.
- (g) The current range and point estimate for Scatterometer represents a "build and store" mode due to the cancellation of the host satellite, N-ROSS. Currently targeted for launch aboard Japanese ADEOS satellite in 1995, the development budget will require additional funding should selection and approval occur.

5. Please provide an analysis of the effect of inflation on the aggregate buying power of NASA.

National Aeronautics and Space Administration

EFFECT OF INFLATION ON NASA BUDGET

COMPARATIVE PURCHASING POWER INDICES FY 1973 - 1990

	GNP Price/Deflator (\$)	NASA Aerospace ^{2/} Price Deflator (\$)	Budget Outlays - Millions of Dollars	
			Actuals	Constant FY 1973
			3/	4/
FY 1973	100.0	100.0	3315	3315
FY 1974	91.7	93.3	3256	2984
FY 1975	83.5	84.2	3267	2727
FY 1976	78.5	77.2	3669	2879
FY 1977	73.5	71.2	3945	2901
FY 1978	68.5	66.0	3983	2729
FY 1979	62.9	60.3	4197	2641
FY 1980	57.7	54.5	4852	2801
FY 1981	52.6	49.1	5426	2856
FY 1982	49.5	44.9	6035	2985
FY 1983	47.6	42.3	6664	3172
FY 1984	45.9	40.0	7048	3235
FY 1985	44.6	38.4	7318	3262
FY 1986	43.4	37.2	7403	3213
FY 1987	42.0	35.9	7592	3189
FY 1988 ^{5/}	40.6	34.5	9092	3690
FY 1989 ^{5/}	39.1	32.9	10678	4176
FY 1990 ^{5/}	37.8	31.3	12707	4796

1/ Department of Commerce, Bureau of Economic Analysis.

2/ Reflects labor intensive nature of NASA purchases using aerospace related inflation data.

3/ Constant FY 1973 outlays calculated using the NASA Aerospace Price Deflator.

4/ Constant FY 1973 outlays calculated using the GNP Price Deflator.

5/ Current estimates.

- 6. Please furnish, by major program, the unobligated balance of funds for FY 1988 and FY 1989 and the actual or estimated carry over from FY 1988 as of January 15, 1989.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
 UNOBLIGATED BALANCES BY MAJOR PROGRAM 9/30/88, 12/31/88 & 9/30/89
 (Millions of Dollars)

APPROPRIATION/PROGRAM	FY 1988 & PRIOR UNOBLIGATED BALANCE 9/30/88	FY 1989 UNOBLIGATED BALANCE 12/31/88	ESTIMATED UNOBLIGATED BALANCE 9/30/89
RESEARCH AND DEVELOPMENT.....	518.3	3,348.9	219.3
SPACE STATION.....	37.2	719.0	45.0
SPACE TRANSPORTATION			
CAPABILITY DEVELOPMENT.....	174.3	338.7	34.1
PHYSICS AND ASTRONOMY.....	99.2	579.3	36.7
LIFE SCIENCES.....	6.7	83.3	3.9
PLANETARY EXPLORATION.....	18.0	271.0	20.0
SPACE APPLICATIONS.....	38.7	438.0	38.1
COMMERCIAL PROGRAMS.....	42.4	35.3	2.2
SPACE RESEARCH AND TECHNOLOGY.....	37.0	246.9	14.0
TRANSATMOSPHERIC RESEARCH			
AND TECHNOLOGY.....	4.3	86.9	3.3
AERONAUTICAL RESEARCH AND			
TECHNOLOGY.....	32.1	315.4	29.2
SAFETY, RELIABILITY AND			
QUALITY ASSURANCE.....	2.3	18.0	1.1
TRACKING AND DATA ADVANCED			
SYSTEMS.....	5.3	14.1	8.9
SPACE FLIGHT, CONTROL AND DATA COMMUNICATIONS....	1,333.2	3,158.6	743.3
SHUTTLE PRODUCTION AND			
OPERATIONAL CAPABILITY.....	1,379.3	826.9	387.9
SPACE TRANSPORTATION OPERATIONS....	188.9	1,701.0	119.5
SPACE AND GROUND NETWORK,			
COMMUNICATIONS AND DATA SYSTEMS..	75.0	629.9	35.9
CONSTRUCTION OF FACILITIES.....	88.6	232.6	110.0
RESEARCH AND PROGRAM MANAGEMENT.....	0.0	1,407.1	0.0
TOTAL, NASA.....	2,154.3	8,159.2	1,886.6

87/81 1/25/89

Question 7:

In accordance with Rule XI, Clause 2(1)(4) of the Rules of the House of Representatives, the Committee is required to include in the report accompanying the NASA authorization bill an assessment of the impact of the legislation on inflation. Please provide the Committee with any information or reports which would be useful to the Committee in fulfilling this requirement.

Answer 7:

In accordance with Rule XI, Clause 2(1)(4) of the Rule of the House of Representatives this legislation is assessed to have no adverse long-run inflationary effects on prices and cost in the operation of the national economy. NASA expenditures are labor intensive, with approximately 80 percent of spending directly for jobs and the remainder for materials. In FY 1989, NASA will employ about 23,150 civil servants and support about 184 thousand contractor and support services employees. Assuming a multiplier effect of 2.5, the total, short-run employment effect on the United States' economy in FY 1989 is about 517,000 jobs. In FY 1990, NASA will employ 23,700 civil servants and support about 212 thousand contractor and support services employees. Assuming a multiplier effect of 2.5, the total short-run employment effect on the United States economy in FY 1989 is about 588,000 jobs. This represents less than one-half of one percent of the total civilian labor force in the United States--too small to have a significant national effect. There could be some specific cases of industrial and regional employment and price changes influenced by NASA expenditures.

The most significant economic effects of NASA spending is the long-run productivity advance from new technologies developed for the space and aeronautics programs. Many NASA-sponsored advances in air and space transportation, communications satellites, remote sensing satellites, and other innovations have improved the productive capacity of industry and stimulated the development and growth of many new businesses.

NASA is actively pursuing its role to expand the opportunities for private industry to gain access into space effectively and economically use space for commercial ventures. These expanded business opportunities have stimulated and are expected to continue to stimulate more productive, noninflationary private sector economic growth, job creation and improve the United States competitive economic position in the world, e.g., improve United States trade balance.

PRE-AUTHORIZATION QUESTIONS SUBMITTED BY THE
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
ON NASA'S FY 1990/1991 BUDGET

QUESTION 8:

Please provide an estimate of the dollar cost of the Challenger accident, including:

- a. Replacement of lost hardware and equipment
- b. Investigations and analysis
- c. Hardware fixes and improvements
- d. Hardware recertification
- e. Delays and related impacts on other NASA, DOD, foreign and commercial programs.

The costs for many of the impacts of the Challenger accident are well defined, particularly when flight hardware is being procured or new stand-alone activities have been initiated. The impacts that have a recurring nature, however, have become part of the baseline program and the distinction between these activities and the ongoing changes in the program precludes segregating these costs. The following impacts were estimated last year prior to the return of the Shuttle to flight status. The impacts were calculated through FY 1991, against the pre-accident budget runout.

- a. The estimate for the replacement orbiter vehicle, the main engines and associated support equipment, including the remote manipulator system, is \$1.9 billion. In addition, the replacement TDRSS and IUS support equipment costs are approximately \$250 million.
- b. Investigations and analysis, including FMEA/CIL reviews and added engineering and SR&QA manpower throughout the program will cost approximately \$850 million.
- c. Hardware fixes and improvements, identified prior to the return to flight, including the SRB redesign, and additional SSME testing, cost about \$2.6 billion. This estimate also covers operations changes, including increased manpower at KSC.
- d. Recertification efforts are generally included in the investigations and analysis and hardware fixes and improvements (8 b. and 8 c.) estimates. These are disdirect recertification efforts on the SRB project that were projected to cost approximately \$180 million.
- e. Delays & related impacts on other programs through FY 1991 were:
 - Net Cancelled STS Flights - \$1.9 billion
 - Major Science Projects - \$650 Million
 - Expendable Launch Vehicles - \$.9 Billion
 - Upper Stages - \$225 Million
 - Tracking Station Extensions - \$135 Million

WRITTEN QUESTIONS SUBMITTED BY THE
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
ON NASA'S FY 1990/1991 BUDGET

QUESTION 9: Please provide a complete tabulation of all currently approved and anticipated fixes or improvements in Space Shuttle hardware and facilities, that have not been completed as of October 1, 1988, including:

- a. Name of fix or improvement
- b. Reason for fix or improvement (e.g., improve safety, enhance performance, etc.)
- c. Cost of fix or improvement
- d. Date fix or improvement will be complete

ANSWER 9: There are several major improvements to Shuttle hardware and facilities which are in work and which comprise a significant portion of the budget. They are listed in Enclosure 1. This enclosure lists these changes, the reason for the change, the estimated date of completion, estimated total cost, and for flight hardware, the FY 1990 portion of that cost. In addition, there are a large number of small changes which are incorporated in the various contracts, but the cost status of which are not discreetly tracked. These are included in Enclosure 2. In the case of the Orbiter, they are primarily return-to-flight modifications still open after October 1, 1988, for incorporation into Atlantis and Discovery.

ENCLOSURE 1

MAJOR FLIGHT HARDWARE AND FACILITY CHANGES

SPACE SHUTTLE MAIN ENGINE

Alternate Turbopump Development

This is a Rocketdyne subcontract let to Pratt and Whitney to develop improved liquid oxygen and liquid hydrogen high pressure turbopumps which incorporate improved safety margins through the use of precision casting in lieu of welding and other increased structural margin components. The pumps are scheduled to make a first flight in mid-FY 1992. Current cost estimate is \$329 million through runout.

External Heat Exchanger

The external heat exchanger is a safety improvement designed to remove the potential for a catastrophic failure of the SSME should the present heat exchanger mounted internally develop a leak. The external heat exchanger will first fly on OV-105 in FY 1992 and is funded out of that account. Current cost estimate for development is \$28 million, with fleet implementation on flight engines an additional \$35 million.

Phase II+ Powerhead Development

The Phase II+ powerhead is an improved design which will provide a better engine environment and safety margins while decreasing weight and complexity. It is scheduled for flight implementation in FY 1995. The cost for development and certification is about \$534 million. The production of the Phase II powerhead is underway and the cost of implementation on flight engines is estimated to be \$73 million.

Produceability

In addition, there is an ongoing produceability program designed to improve manufacturing techniques for the main engine which result in a lower cost to manufacture each engine. Funding for this element is approximately \$13 million per year.

Product Improvement

The product improvement program is designed to improve engine component margins and reliability while extending hardware life limits. This will reduce critical failure modes and hazards while improving the reuseability of engine hardware. Funding is approximately \$23 million per year.

SOLID ROCKET MOTOR/SOLID ROCKET BOOSTER

Solid Rocket Motor Contamination Control

As an improvement to the manufacturing process, Thiokol is revising their contamination control procedures. This should result in improved process flow and reduced cost. The estimate is approximately \$25 million, most of which will be incurred in FY 1989.

Advanced Solid Rocket Motor

Advanced Solid Rocket Motor development will start in FY 1989. This program will produce 12,000 lbs. more payload to orbit as well as improve safety designed in solid boosters. The current estimate for this program is \$1.5 billion through FY 1994, excluding any facilities costs.

ORBITER

General Purpose Computers

We have redesigned the general purpose computers, increasing their speed and memory capacity. This program is almost complete and will cost about \$79 million through runout. Installation and checkout will be complete in FY 1991. First flight is scheduled for STS-42.

Improved Alternate Inertial Measurement Unit

This program also upgrades the orbiter inertial measurement units to improve performance, upgrade obsolete technology, and decrease logistics costs. Total cost through runout is \$53 million. Fleet implementation is scheduled to be complete in FY 1991.

Improved Auxiliary Power Unit

This activity is also to improve subsystem performance and to increase the life expectancy of turbine wheels and other mechanical components. Most of the work has been completed; and fleet implementation is scheduled to be complete in FY 1991. The total cost is approximately \$34 million.

Carbon Brakes

This program is to improve the orbiter brakes and increase safety margins during mission landing. This program will be complete in FY 1990 with the delivery of the final sets of brakes to the replacement orbiter. Total cost of the program is \$13 million.

14-Inch Disconnect

This is a redesign to the Orbiter/External Tank umbilical disconnect to improve safety margins and simplify the operating mechanism. The development is funded in the replacement orbiter budget, with fleet implementation in the baseline budget. The total cost is \$26 million. Fleet implementation is scheduled

ORBITER (continued)

Orbiter Drag Chute

→ This is another safety improvement to the landing phase of the mission. The drag chute will allow the orbiter to land with increased stopping power and control. The program is in the replacement orbiter budget, with fleet production funded in the baseline budget. The total estimated cost is \$30 million. The program is scheduled to be completed in mid-FY 1992.

Improved Nose Wheel Steering System

This also is a landing safety improvement, permitting the crew increased control during the roll-out after landing. Its development is also funded under the replacement orbiter program, with fleet implementation in the baseline budget. The program is scheduled to be complete in late FY 1992. The total cost is \$9 million.

Solid State Star Tracker

This program is to develop a replacement star tracker for the orbiter to replace the no-longer-in-production NASA standard star tracker. This is also funded under the replacement orbiter. The total cost is \$9 million. This program will be complete in FY 1992. ←

ENCLOSURE II

MINOR FLIGHT HARDWARE CHANGES

MISCELLANEOUS SMALL CHANGES GROUPED BY PROJECT AND CATEGORY

This enclosure lists a series of relatively small changes which are in the program or which are proposed, but for which we do not track the costs explicitly once they are incorporated in the contracts. Therefore, we have been unable to provide a cost estimate for their completion. In general, however, the are less than \$300 thousand each; and typically are less than \$100 thousand each.

The reasons for the changes fall into three general categories:

- I Safety-of-Flight
- II Performance Enhancement
- III Turnaround Enhancement/Serviceability/Long-Term
Cost Savings

The reason for each change is indicated.

HARDWARE

SRM APPROVED CHANGES FOR IMPROVED MARGIN

	<u>STATUS</u>
Non-threaded bolt needed to accommodate stat-o-seal on nozzle joint #5	
Allow use of high tolerance o-rings for S&A rotor shaft	STS-29
Igniter heater and power cable installation	STS-27
Replacement of EPDM with KSNA on aft segment stiffener stubs	STS-30
Adjustable vent port plugs with Nylok fastener feature; leak check port plug with Nylok fastener feature	STS-29
Venting of Joint Protection System changing position and retainer band trunnions to point away from the ET and Orbiter	STS-29
Teflon strip installation at Factory joint near EPDM edge bond to preclude tearing of EPDM during joint expansion	STS-26
Locking feature for nozzle leak check port plugs	TBD
Design and fabricate foam core system tunnel	TBD

EXTERNAL TANK FOR IMPROVED MARGIN

First tank number to incorporate change. Subsequent tanks also have change

Incorporation Plasma Arc welding	
One half dome body weld assembly	ET-44
Dome Quarter Panel to Dome	
One-half body weld assy	ET-47
L02 forward ogive weld assy	ET-42
ET Dome to Chord Weld	ET-49
ET Dome Gore to Gore Weld	ET-47
LH2 Tank Fwd Dome Circumference Weld	ET-74
LH2 Tank Fwd Dome Circumference	ET-70
L02 Tank Major Circumference Weld	ET-74
L02 Aft Ogive	ET-74

<u>EXTERNAL TANK FOR IMPROVED MARGIN (Cont'd)</u>	<u>STATUS</u>
Elimination of Non self locking standard length thread inserts	ET-40
Incorporate Dual Spray Gun Concept & Selected Design Changes on the Intertank	ET-31
Revise Design and Installation of Cable Attach Clips on LH2 Fwd & Aft Domes	ET-23
Change of Seal Standards	ET-51
Add Rubber Dam In Forward LO2 Tank Cable Tray Segment for Aeroheating Protection	ET-22
Change Stroke Limiter from 1.1 inch to 1.5 inch in the G02 Vent Relief Valve	ET-40
SLA deletion from LO2 Tank and MA25 S Deletion from Barry Mounts	ET-51
Additional Proof Test for LO2 Feedline BSTRA Oad to Housing Fillet Weld	ET-61
<u>SOLID ROCKET BOOSTER ASSEMBLY FOR IMPROVED MARGIN</u>	
Incorporation of ripstop on main parachute	STS-34
Incorporation of MSA-2	STS-29
Adaption of an improved APU turbine wheel	TBD
<u>SPACE SHUTTLE MAIN ENGINE FOR IMPROVED MARGIN</u>	
Modification of FASCOS to prevent erroneous engine cutoff	TBD
AR01 - Computer Software Modification	STS-29
Bearing modifications and improvements	TBD
Blade improvements	TBD
Elimination of preburner pops	TBD
Hot Gas Sensor improvement	TBD
Large Throat Main Combustion Chamber	TBD

FACILITIES IMPROVEMENTS

CURRENTLY APPROVED FIXES OR IMPROVEMENTS FOR KSC PROJECTS

1. Launch Complex 39 Operations Support Building

This facility will provide permanent office facilities to Shuttle support personnel, enabling them to maintain the planned STS flight rate. Approximate cost, including the building's equipment, is \$27.9M with scheduled completion in June 1990.

2. Launch Complex 39 Pad A Rehabilitation and Modification

Work on the facility involves upgrading of fixed service structure elevators and replacement of the payload changeout room wall panels to enhance personnel, Shuttle systems, and payload safety at the launch site. Approximate cost is \$24.3M with scheduled completion in October 1989.

3. Upgrade of the Orbiter Modification and Refurbishment Facility (OMRF) to Orbiter Processing Facility 3 (OPF-3)

This upgrade provides for a third processing bay to satisfy requirements for orbiter structural inspection, checkout, and safing operations necessary to meet the planned flight rate. Approximate cost is \$88.4M with scheduled completion in September 1991.

4. Mobile Launch Platform 3 (MLP-3) Activation

This project modifies the MLP-3 to look like MLP-1 and MLP-2 and incorporates post-Challenger return to flight modifications. Approximate cost is \$8.8M with scheduled completion in September 1989.

5. Fiber Optics Installation between Facilities

This project, involving numerous facilities, replaces/supplements existing copper cable capability to allow for the higher data handling requirements of future missions. Approximate cost is \$12.1M with construction of the system supporting the Shuttle facilities estimated for completion by FY 1991.

6. Operational Intercom System-Digital (OIS-D)

This project funds the replacement of an outdated OIS-RF (radio frequency) system with a digital system that will allow support for multiple Shuttle processing flows and reduce the system's overall maintenance requirements. Numerous KSC facilities are involved, with hardware installation in Shuttle support areas to be completed in FY 1992. The approximate system cost is \$33.6M.

7. Launch Processing System Upgrades (LPS)

To enhance performance of the total LPS network (located in numerous Shuttle processing/support areas) upgrades to the computer hardware are required. Phased implementation of hardware and associated software will continue into the mid-1990's. Approximate cost of the LPS upgrades is \$172.2M.

8. Shuttle Processing Data Management System (SPDMS II)

This project funds computer hardware, software, documentation, and processing systems that will provide technical and management information to support increasing flight rates. System cost is approximately \$47.5M, with operational readiness scheduled for early FY 1992.

9. Upgrade of a Low Power Radar Wind Profiler at KSC

The upgrade of the radar wind profiler will increase wind data resolution to samples every 150 meters from an altitude of 1.5 to 18 Km directly over the KSC area. The upgrade will also optimize system software so that a vertical profile of wind can be generated every 5 to 10 minutes. Wind and wind shear information will support dynamic load assessment for safe Shuttle launch. Approximate cost is \$1.0M with scheduled completion in September 1989.

10. Airborne Field Mill (ABFM) Measurement Program at KSC

An ABFM measurement program is needed to safely revise the natural and triggered lightning launch commit criteria (LCC). Electric field data will be collected over a 12 month period using 100+ Learjet flight hours. The generated data base will be the foundation for revising weather-related LCC and determining the need for ABFM measurements to be made on the day of launch. Approximate cost is \$1.4M with scheduled completion in September 1989.

11. Ground-Based Field Mill (GBFM) Upgrade Program at KSC

The GBFM network at KSC is being upgraded to improve reliability, sensor calibration routines, and maintainability. It will use state-of-the-art electronics to enhance NASA's ability to identify triggered lightning potential for launch and landings. Approximate cost is \$650K with scheduled completion in September 1989.

CURRENTLY APPROVED FIXES OR IMPROVEMENTS FOR JSC PROJECTS

1. Mission Control Center (MCC) Upgrade

The upgrade replaces obsolescent computers/equipment, including the consoles in the Flight Control Rooms, and introduces performance enhancements to enable the MCC to support the planned flight rate. Approximate cost is \$281.3M with scheduled completion in October 1994.

2. Shuttle Mission Simulator (SMS) Upgrade

The upgrade includes the replacement of SMS host computers, development of an ascent/entry trainer, and SMS enhancements to provide additional flight training capacity and increased flight rate capability in support of the planned flight rate. Approximate cost is \$241.9M with scheduled completion in November 1994.

3. Mission Evaluation Room (MER) Upgrade

The MER Upgrade includes equipment replacement and hardware and software enhancements that are required to make the MER compatible with the upgraded MCC. Approximate cost is \$4.4M with scheduled completion in FY 1993.

4. Software Development Facility/Software Production Facility SDF/SPF Upgrade

The SDF/SPF Upgrade includes host-computer replacement and hardware/software enhancements so that the SDF/SPF can be utilized to develop and produce more-reliable flight software in support of the planned flight rate. Approximate cost is \$35.0M with scheduled completion in January 1994.

5. Swing Flight Control Room (FCR)

The Swing FCR will connect the computer systems in the MCC third floor secure FCR with the computer systems of the second floor FCR, enabling the third floor FCR systems to be used to support non-secure operations. This requirement is due to an increase in the number of unclassified flights. Approximate cost is \$5.4M with scheduled completion in FY 1993.

6. Flight Analysis and Design System (FADS)

FADS is a planned upgrade of the present flight design system, which is used to plan each mission from launch through landing. FADS is required to improve system performance and reliability while adding safety features. Approximate cost is \$46.3M with scheduled completion in FY 1994.

7. DOD Shuttle Transportation System (STS) Downmoding

This is a realignment of planning, training, and support systems from the support of DOD classified interfaces with the STS to the support of unclassified interfaces with both civil and DOD payloads. Approximate cost is \$98.3M with scheduled completion in FY 1994.

8. Information Management Information Computer (IMIC)

The IMIC facility Serves as the host computer system for the Program Compliance and Assurance Status System (PCASS). This database is being developed post 51-L as part of the System Integrity Assurance Program Plan (SIAPP), recommended by the Rogers Commission. Approximate cost is \$51.3M with scheduled completion in FY 1994.

9. T-38 Pacer Classic

This structural upgrade, which impacts safety, is primarily to extend the T-38 operating life. The requirements are defined by the USAF program. The NASA T-38's are integrated into the military work schedule. Approximate cost is \$27.5M with scheduled completion in FY 1994

10. T-38 Dorsal Longeron

This is a Time Compliance Technical Order (TCTO) for a safety modification of the dorsal longeron. This increases the safety factor and associated structural integrity of the aircraft upper surface longeron. Approximate cost is \$5.8M with scheduled completion in FY 1991.

11. T-38 Weather Radar/Avionics Upgrades

This program will add weather radar capability and upgrade the flight instrumentation displays in the T-28 aircraft fleet. The weather radar capability would allow the aircraft to detect/avoid weather risks and would increase overall flight safety. Approximate cost is \$12.1M with scheduled completion in FY 1993.

12. Shuttle Training Aircraft-4 (STA-4) Purchase/MODS

This provides for the purchase and modification of a Gulfstream II Aircraft to be used as a fourth STA. This purchase was required to supplement the existing STA fleet to support training requirements associated with the increased flight rate beginning in the early 1990's. Approximate cost is \$23.5M with scheduled completion in FY 1991.

13. Shuttle Carrier Aircraft II (SCA-II) - Purchase & Modification

This provides for purchase and modification of a Boeing 747 jetliner (used) for use as a backup SCA. This eliminates a potential single-point failure in the Space Shuttle Program. Approximate cost is \$61.7M with scheduled completion in FY 1991.

14. Improvement of the Abort Landing site at Yundum International Airport, Banjul, The Gambia

Upgrade current facilities to provide the full capabilities of a Transoceanic Abort Landing (TAL) site. Current status is that of an Augmented Contingency Landing site. The pending upgrade, which involves increasing the available runway rollout distance, will enhance safety and relieve launch constraints by providing a weather alternate for Ben Guerir, Morocco, when Moron, Spain is unavailable due to ascent performance limitations. Anticipated improvements include construction of a safing and deservicing area.

\$1.6M has been approved to support status as Augmented Contingency Landing Site. \$1.9M is now pending. \$3.2M is anticipated for future work.

Scheduled completion date for approved work is 9/89. Pending upgrade is targeted for completion by 1/90.

15. Upgrade of Microwave Scan Beam Landing System (MSBLS) units

Five single "stand alone" MSBLS units will be modified so that they may be linked in tandem with each other to prevent a loss of signal should the primary unit fail. Upgrade will allow automatic switching of functions to a standby unit with no significant signal loss. Approximate cost is \$1.6M with scheduled completion in December 1989.

16. Shuttle Orbiter Arresting Barriers (SOAS)

The SOAS is a device designed to arrest forward progress of the Shuttle after touchdown at a landing site where there is limited runway rollout distance available. The devices are to prevent an Orbiter from overrunning the available runway as might occur in case of a brake failure. Three units have been installed at abort landing sites in Spain (two) and in The Gambia. A fourth unit is on order. Approximate cost is \$2.4M with scheduled completion in April 1989.

APPROVED OR ANTICIPATED FIXES IN SPACE SHUTTLE
HARDWARE OR FACILITIES

ORBITER MODS

	<u>MODIFICATION NAME</u>	<u>STATUS</u>	<u>REASON FOR MOD</u>
10174	RELOCATION OF CABIN AIR REVITALIZATION SYSTEM/ ATMOSPHERIC REVITALIZATION PRESSURE CONTROL SYSTEM SENSORS	STS-28	II
10455	FUEL CELL OPERATIONAL IMPROVEMENT	STS-28	II
10477	CHIN PANEL INSTALLATION FOR LI2200 TILE	STS-28	I
10570	IMPROVED OXYGEN PARTIAL PRESSURE SENSOR	STS-29	I
10572	16 MM CAMERA INSTALLATION	STS-28	I
10661	REACTION CONTROL SYSTEM PRIMARY THRUSTER	STS-28	I
10791	MAIN LANDING GEAR DOOR BOOSTER REDESIGN	STS-32	III
11014	PARTICLE IMPACT NOISE DETECTION MICROSWITCH	STS-28	I
11018	MAIN PROPULSION SYSTEM 17" DISCONNECT REDESIGN	STS-28	I
11199	REDESIGN GASEOUS OXYGEN FLOW CONTROL VALVE	STS-28	I
	HELIUM LINE		
11311	THERMAL PROTECTION SYSTEM WATERPROOFING WITH DIEMETHOL ETHOXY SILANE	STS-28	I/III
10566	ORBITER BRAKE IMPROVEMENT	STS-31	II
11567	THICK STATOR BRAKES	STS-28	I
11656	OUTBOARD WING TRAILING EDGE TIPS REDESIGN	STS-28	I/III

APPROVED OR ANTICIPATED FIXES IN SPACE SHUTTLE
HARDWARE OR FACILITIES

ORBITER MODS

	<u>MODIFICATION NAME</u>	<u>STATUS</u>	REASON FOR <u>MOD</u>
11710	ET/ORB UMBILICAL HOLDDOWN SPACER (6 EACH)	STS-28	III
11711	MODIFY AFT ATTACH PYROTECHNIC DEBRIS CONTAINERS	STS-28	I
11748	BALANCE BRAKE PRESSURE	STS-28	I
11775	AIRSPED MACH INDICATOR/ALTIMETER VERTICAL VELOCITY INDICATOR RELOCATE COOLING DUCT	STS-28	III
11798	APU ISOLATION VALVE REDESIGN	STS-39	III
11813	ORBITER CONTAMINATION CONTROL	STS-39	III
11817	AFT FUSELAGE WIRE AC HARNESS	STS-28	III
11846	FORWARD REACTION CONTROL SYSTEM AC MOTOR VALVE BELLOW LEAKAGE	STS-52	I
11862	EMERGENCY EGRESS SLIDE LANDING	STS-28	I
11873	MODIFY FUEL CELL WATER RELIEF	STS-28	I
11920	FLASH EVAPORATOR SYSTEM PROTECTIVE COVER	STS-28	III
11944	UMBILICAL HOLDDOWN PINCHED WIRE	STS-28	I
11961	AFT ATTACH DEBRIS CONTAINMENT	STS-28	I
11965	RADAR ALTIMETER ERRONEOUS OUTPUT	STS-28	I
11968	WATER SPRAY BOILER STEAM DUCT TEMPERATURE MEASUREMENT RANGE	STS-28	III
11969	LOSS OF PRESSURANT TO POTABLE WATER TANK	STS-28	III
11989	CLOSED CIRCUIT TV BRACKET BULKHEAD ACTION	STS-28	I
11998	AUXILIARY POWER UNIT DRAINLINE HEATER REWRAP	STS-28	I
12054	IMPROVE SSME QUICK DISCONNECT INSTALLATION	STS-28	I
12060	ORBITER DRAG CHUTE	STS-52	I/III
12119	FUEL CELL WATER PURITY SENSOR	STS-40	II
12134	ORBITER EMERGENCY EGRESS SIDE HATCH	STS-28	I
12135	GENERAL PURPOSE COMPUTER OSCILLATOR REPLACEMENT	STS-28	III
12166	BALANCE BRAKE PRESSURE	STS-28	I

APPROVED OR ANTICIPATED FIXES IN SPACE SHUTTLE
HARDWARE OR FACILITIES

ORBITER MODS

	<u>MODIFICATION NAME</u>	<u>STATUS</u>	REASON FOR <u>MOD</u>
12170	AUXILIARY POWER UNIT FUEL LINE TEMPERATURE TRANSDUCER RELOCATION	STS-28	I
12220	AUXILIARY POWER UNIT FUEL TEMPERATURE MONITORING SYSTEM	STS-32	I
12329	AUXILIARY POWER UNIT INADVERTANT HOT RESTART	STS-50	I
12453	ORBITER TO PAYLOAD CHANGE-OUT ROOM GROUNDING PROVISION	STS-28	III
12494	SRB RATE GYRO ASSEMBLY RECHANNELIZATION	STS-33	I
12506	WING LOAD INSTRUMENTATION	STS-28	I
12518	MID FUSELAGE 6.0 LOADS/FRAME STRUTS	STS-28	I
12615	LEXAN PANEL MODIFICATION	STS-28	III

WRITTEN QUESTIONS SUBMITTED BY THE
SUBCOMMITTEE ON SPACE SCIENCE AND APPLICATIONS
ON NASA'S FY 1990/1991 BUDGET

SHUTTLE ORBITER

QUESTION 10:

Please provide a summary of the current plan for production of the replacement orbiter vehicle including, initial cost estimates, current cost estimates, all changes made as a result of the accident and resulting recommendation, and the itemized costs associated with these changes.

ANSWER 10:

The initial cost estimates for replacing the vehicle hardware lost on STS 51-L was \$2.1 billion. The FY 1988 Appropriations Act reduced this amount by \$225 million. NASA has accepted this reduction, but considers it a management challenge, since there have been unexpected cost growths on previous vehicles. It is early in this program; however, all changes to date can be accommodated. As with the previous vehicle, the cost of changes made to the replacement orbiter (OV-105) will be charged to the vehicle throughout its useful life (30 years).

The baseline configuration for the OV-105, is the same as the previous vehicle, OV-104, with all of the configuration changes up to the time when the contract for the new vehicle was signed including changes as a result of the accident. Since the signing of the contract, there have been other changes made to the design of OV-105 including those to add safety improvements. These changes are also made to the rest of the fleet. In addition to these types of changes, there have been those which were required because of parts obsolescence, improved sequences for production, and minor improvements, which can best be accomplished on a vehicle while it is in production. A list of the contract changes issued for OV-105 is enclosed. The estimate of all changes to date is \$100M.

ROCKWELL OV-105: NAS9-17800 CONTRACT CHANGES

CCA	Description
	1 New structural film adhesive
	2 New Specifications for Window Seal Rubber
	3 Orbiter Tape Recorders
3R1	Delete Reference to BRU/Piece Part Spares
	4 Improve Keel Bridge and IUS Damper Schedules
	5 Enhanced MDM
	6 Removal of MPS transducers
	7 GO2 FCV Redesign
	8 APU GN2 Pressurization Line
	9 Display Driver Unit Intermittent Bite
	10 OMS Pod Option Schedule
	11 Ku-Band Deployed Assembly Coax Cables
	12 Encrypted Bypass Isolation Amplifier Deletion
	13 Orbiter T/O Umbilical Collet Improvement
	14 APU Isolation Valve Redesign
	15 Umbilical Separation Debris Containment
	16 Body Flap Cove Asbestos Seals
16R1	Wording change to CCA 16
	17 FRCS Negative Margin Tiles
	18 KHZ Gimbal Bearing Vibration
	19 Emergency Express Hatch Delta Pressure Spring
	20 Impact Protection for Flash Evaporator
	21 Clevis Nut ET/Orbiter Door Mechanism
	22 Vol. G Stowage Container Pin
	23 Radar Altimeter Antenna Replacement
	24 Enhanced MEC
24R1	Wording change to CCA 24
	25 Micro-MIAS
	26 Air-Cooled Avionics Debris Filters
	27 New GPC Debris Filters
	28 Transportation of VLS GSE
	29 Electrical Equipment Quality Standards
	30 S-Band Single Point Failure
	31 Orbiter Cockpit Upgrade Multifunction Displays
	32 Two (2) Workstands for OV-105
	33 High Accuracy Cabin Pressure Sensor
	34 Mass Memory Units for OV-105
	35 TPS Waterproofing Oven Safety
35R1	TPS Waterproofing Oven Safety (Reducing from 9 to 7)
	36 Camera Installation in LO2 Umbilical Wall
	37 Palmdale GSE Refurbishment Activities
37R1	Inclusion of GSE Share/Rotational Items
	38 OV-105 Configuration Changes (6-7/87)
	39 OV-105 Mid-fuselage 6.0 Loads Modifications
	40 OMS/RCS Pod Attachment
	41 OMS TVS Controller
	42 Orbiter Payload Bay Longeron Grounding
	43 TPS-ET Door Thermal Barrier Spacer Removal
	44 Brake Removal Hazard
	45 Enable Brakes/Anti-skid at MLG Weight-on-Wheels
	46 Hydraulic Accumulator Cylinder Change
	47 Nosewheel Steering Actuator Seal

- 48 APU Fuel Temperature Monitoring System
- 49 Gap Filler Installation/Orbiter Windshield
- 50 Master Timing Unit (Cracked Solder Joints)
- 50R1 Master Timing Unit (transfer of OV-099 assets)
- 50R2 Master Timing Unit (Replacement of CCA 50R1)
- 51 TPS - Rudder/Speedbrake Trailing Edge Tile Redesign
- 52 TPS - OMS Pod Y-Web Door Redesign
- 53 TPS - Main Landing Gear (MLG) Door Thermal Barrier Redesign
- 54 TPS - Negative Margin Tile
- 55 TPS - Ingress/Egress Hatch Pressure Seal Redesign
- 56 TPS - PLBD Hinge Piston Binding Problem
- 56R1 Provide Presentation Date for Study Results
- 57 TPS - Gap Filler/Thermal Barrier Thread
- 58 New Television Monitor Design
- 59 Modifications of MSBLS Frequency
- 60 Portable Foot Restraint Stowage Assembly Mod
- 61 Mid-Fuselage & PLBD Hinge Supports Negative Margins of Safety
- 61R1 Mid-Fuselage Carry-Thru Strut
- 62 New Build GSE for OV-105
- 62R1 Additional Cables
- 62R2 Rescind Authorization to Purchase Additional Cables
- 63 Fuel Cell Water Purity Sensor Test Circuit
- 64 OV-105 Tooling Requirements
- 65 OV-105 Orbiter Emergency Egress Change
- 65R1 OV-105 Orbiter Emergency Egress Change (Crew Escape Tractor Rocket Deletion)
- 65R2 OV-105 Orbiter Emergency Egress Change (GFE Debris Catcher)
- 65R3 OV-105 Orbiter Emergency Egress Change (Egress Slide to Sidewall (Lower Beam) Gap Closeout)
- 66 APU Water Valve Study
- 66R1 Provide Presentation Date for Study Results
- 67 RCS Regulator Redesign
- 68 Water Spray Boiler Instrumentation Change "B" Controller
- 68R1 Includes requirements for telemetry and software data
- 69 Orbiter Window Viton Seals
- 69R1 Perform Analysis for Replacement of Orbiter Window Viton Seals
- 70 Nosewheel Steering Study
- 71 OMS POD Structural Negative Margins
- 72 Freon Loop Colplate Cooling Performance Monitoring Improvements
- 73 Orbiter Drag Chute
- 73R1 Administrative Change
- 73R2 Orbiter Drag Chute
- 74 Wing Spar Adhesive
- 75 APU Turbine Wheel Development
- 76 Water Spray Boiler Liquid Level Sensor Bonding
- 77 OMS Crossfeed Line Pressure Instrumentation
- 78 TPS Life Measurements
- 79 TPS Spec Updates for Production Operations
- 80 TCS Snap Fasteners
- 81 Hazardous Gas Detection for the LH2
- 82 Mod of Orbiter/SSME Hydraulic Quick Disconnect

- 83 TPS Location "A" Mods for ETR, and WTR, transferred from NAS 9-14000
- 84 Wing Structural Mod Kits Transferred from NAS 9-14000
- 85 JAY-EL Relay Solder Problem
- 86 Addition of Strain Gages & Temp. Measurements to Wings & Mid-Fuselage
- 87 Ku-Band Changes and Issues
- 88 OMS Deck Frames Negative Margins (6.0 Loads)
- 89 14 Inch Disconnect
- 89R1 14 Inch Disconnect, Terminate 17 Inch Disconnect
- 90 Structural Spares Transfer
- 91 Crew Compartment Cable Routing STS-26 and Subs
- 92 New TACANS for OV-105
- 93 EEE Parts Requirements Reduction
- 93R1 Replacement of OPPL D Requirements to reflect OPPL B plus requirements
- 94 Deletion of Single Point Failure in Orbiter Kill Power Switch
- 95 ET Door Thermal Barrier Change
- 96 Fuselage Stub Tile Bond Overtemp
- 97 APU Improved Controller
- 98 Waste Management Compartment (WMC) AFT Wall Assembly Support Structure Strengthening
- 99 Orbiter Structural Mods - Rail Installation
- 100 Redundant Operational Brake Pressure
- 100R1 Cancels CCA 100
- 101 Critical Tail Access for Structural Inspections
- 102 Fuel Cell H2O Nozzle Heater Temperature Controller
- 103 Improved Nosewheel Steering System
- 103R1 Study on Uncommanded Brake Pressure
- 104 Options for OV-105 Waste Collection System (WCS)
- 105 TPS Redesign for Antenna/Structural Access
- 106 Fuel Cell Powerplant
- 107 Crew Escape System Pole Extraction Option
- 107R1 Crew Escape System Pole Extraction Option (Galley Light Removal)
- 108 Thrust Structure Negative Margin Lugs
- 109 Smoke Detector Upgrade
- 110 External Tank Orbiter 2 and 4 in. Disconnect
- 111 Elevon Blade Seal Guide Pin Weld Redesign
- 112 Improved APU Fuel Pump Seal Redesign
- 113 Study to Define Locations Requiring TPS Redesign
- 114 Install Strain Gages on OV-105 to Support Modal Survey Structural Inspection
- 115 GFE/EVA Slidewire (Part No. Change)
- 116 In-Flight Maintenance Issues: Koropon on Fasteners
- 117 Redesign of Light Shade Shutter Mechanism
- 118 Improved Marking Techniques for OV-105
- 119 Hydraulic Component Contamination
- 120 OMS Deck Frame Loads Reduction
- 121 MPS 750 Regulator Orifice Restriction & Seal Change
- 122
- 123 Hydraulic Recirculation Pumps for OV-105
- 124 Egress Hatch/Fwd Fuselage Seal Lightning Protection
- 125 Side Hatch Actuator Knob Mod
- 126 ET Door Actuator Haydon Switch Resolution
- 127 Star Tracker Upgrade

- 128 Head Up Display High Voltage Power Supply
(HVPS) Problem
- 129 Reaction Control System (RCS) Primary Thruster
1 Instability Program
- 130 OMS Propellant Gaging System Acceptance Test
Requirements
- 131 Water Pump Nozzle Redesign
- 132 Orbiter Side Hatch GSE Attachment Improvement
- 133 Vents 4/7 Deletion
- 134 Nose Landing Gear/Main Landing Gear Uplock Design Study
- 135 6.0 Wing Box and Glove Mods
- 136 Wing Mod Upper Skin and 1307 SPAR
- 137 6.0 Loads - Wing Beef-up SPAR Webs Xol307 and Xol365
- 138 Deletion of NHB 5300.4
- 139 Pulse Code Monitor - Modulating Unit (PCM-MU)
Toggle Buffer Change
- 139R1 Pulse Code Modulation - Master Unit (PCM-MU) Toggle
Buffer (title correction)
- 140 Fabrication of FRCI 12 Tiles Using Elliptical Cross
Section Nextel Fiber
- 141 Main Landing Gear Uplock Release Thruster
(part number change)
- 142 Fifth Cryo Tank Set for OV-105
- 143 Redesign FRSI Strip at Top of X01307 Bulkhead
- 144 Flash Evaporator/Water Spray Boiler Electrical
Connector
- 145 TPS PLBD Hinge SIP Erosion Fix
- 146 TPS Outboard Elevon Oversize Tile
- 147 TPS Vent Door Thermal Barrier Redesign
- 148 Rotary Switch Shaft Redesign
- 149 Crew Seat Relocation and Reinforcement Study
- 150 TPS - Ingress/Egress Hatch Pressure Seal Redesign
- 151 Mini ET/SRB Electrical Verification Unit
- 152 TPS Thermal Barrier Installation Specification
- 153 PCA Changes MPS Cross-Over Diodes
- 154 Dome Heatshield Blanket Improvements Plan
- 155 Orbiter Drain Hole Inspection Provisions
- 156 AC Motor and Manual Valve Bellows Weld Porosity
Inspection Improvement
- 157 Remove Hydraulic System Freon Heat Exchangers Study
- 158 Crewman Optical Alignment Sight Assembly STS-26
Inflight Anomaly, Car No. 26RF02
- 159 Payload Cryogenic Hydrogen Venting
- 160 R-120 Repair of Delaminated RCC Panels
- 161 Study of the State of Art Fasteners
- 162 Improved Oxygen Partial Pressure (PP02) Sensing Device
- 163 NLG Extend Pyro Powered Assist Connector Redundancy
and EIU 1 Command Path Rechannelization

- ✓11. Please submit a full documentation of NASA's reimbursable obligations, by major program, and identify the source of these reimbursements. The documentation should be at the same level of detail as that for directly funded programs.

FY 1990 SUMMARY
REVENUE SUMMARY
(Millions of Dollars)

	FY 1989	FY 1990	FY 1990
RESEARCH & DEVELOPMENT	644.8	747.4	552.3
SPACE TRANSPORTATION CAPABILITY DEV	117.5	165.4	100.2
DOO	111.3	92.2	90.3
DOA	1.8	2.3	1.5
Other Federal	2.6	4.5	3.5
Non-Federal	1.6	3.2	1.3
SPACE SCIENCE & APPLICATIONS	209.0	510.8	350.2
PHYSICS & ASTRONOMY	7.9	0.0	7.0
DOO	5.2	5.0	3.4
DOA	2.7	3.0	4.3
Other Federal	0.1	0.4	0.1
Non-Federal	0.1	0.4	0.1
LIFE SCIENCES	261.8	501.6	340.2
DOO	230.1	247.4	104.8
DOA	111.7	242.8	165.3
Other Federal	9.2	9.0	7.5
Non-Federal	1.8	0.4	0.4
COMMERCIAL PROGRAMS	2.3	5.6	5.1
DOO	2.1	1.1	0.0
DOA	4.0	2.3	2.8
Other Federal	4.4	0.9	0.0
Non-Federal	4.4	0.9	0.0
AERONAUTICAL RESEARCH & TECHNOLOGY	60.0	69.2	43.3
DOO	50.2	59.0	30.0
DOA	12.4	9.4	5.3
Other Federal	20.2	32.7	25.1
Non-Federal	11.2	27.1	19.7
SPACE RESEARCH & TECHNOLOGY	0.0	0.0	0.0
DOO	0.0	0.0	0.0
DOA	0.0	0.0	0.0
Other Federal	0.0	0.0	0.0
Non-Federal	0.0	0.0	0.0
TRANSFORMER RESEARCH & TECHNOLOGY	1.2	0.7	0.1
DOO	1.2	0.7	0.1
DOA	0.0	0.0	0.0
Other Federal	0.0	0.0	0.0
Non-Federal	0.0	0.0	0.0
ENERGY TECHNOLOGY	21.4	21.0	21.0
DOO	0.0	0.0	0.0
DOA	0.0	0.0	0.0
Other Federal	0.0	0.0	0.0
Non-Federal	0.0	0.0	0.0
SAFETY, RELIABILITY & QUALITY ASSURANCE	2.0	1.4	1.5
DOO	2.0	1.4	1.5
DOA	0.1	0.0	0.0
Other Federal	0.1	0.0	0.0
Non-Federal	0.1	0.0	0.0

	FY 1988	FY 1989	FY 1990
SPACE FLIGHT, CONTROL & DATA COMMUNICATIONS	232.1	222.9	188.9
-----	-----	-----	-----
SHUTTLE PRODUCTION & CAPABILITY DEVELOPMENT	135.7	78.4	72.3
-----	-----	-----	-----
ROD	135.7	78.4	72.3
SHUTTLE OPERATIONS	0.0	12.4	0.0
-----	-----	-----	-----
Non-Federal	0.0	12.4	0.0
EXPENDABLE LAUNCH VEHICLES	162.8	106.3	65.0
-----	-----	-----	-----
ROD	95.5	34.0	0.0
NOAA	51.6	49.6	65.0
Other Federal	15.7	2.7	0.0
SPACE & GROUND NETWORK, COMMUNICATIONS & DATA SYSTEMS	32.6	20.6	50.4
-----	-----	-----	-----
ROD	20.9	20.4	29.1
NOAA	9.4	9.5	7.3
Other Federal	0.0	0.0	0.2
Non-Federal	3.3	0.0	13.8

42. Please provide an estimate of planned reimbursements from the Department of Defense for the provisions of Space Shuttle services and a schedule for such services for fiscal years 1990 through 1993.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PLANNED SHUTTLE REIMBURSEMENTS - DOD

	FY90	FY91	FY92	FY93
Planned Shuttle Flights (equivalents)	3.0	2.7	2.0	2.0
Application of prior flight credits (1)	-3.0	-2.7	-0.4	
Shuttle flights for reimbursements	0.0	0.0	1.6	2.0
Reimbursements (2)	0.0	239.8	305.4	323.8

(1) Represents flights paid for however not flown yet

(2) Reimbursements are received one year prior to flight and are based on price of \$115 million (866).

Question 13: Please provide a summary of contracts and amount of such contracts entered into with foreign entities by fiscal years 1990 through 1993.

Answer: NASA has not previously collected data to specifically identify whether the awardee of a contract is a foreign entity. We do, however, have information on contracts where the place of performance is outside the United States. Enclosed are listings of contracts awarded in fiscal years 1984 through 1988 where the place of performance was outside the U.S. Many of the firms on the lists are not foreign entities, and there may be other contracts being performed by foreign entities in the U.S. However, beginning with fiscal year 1989, we have changed our data collection to enable us to identify awards to foreign entities. While there will be some judgement involved concerning multinational firms and U.S. subsidiaries of foreign firms, but future data should be far more accurate.

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1988

COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FFF
DESCRIPTION			
ASIA	NASING CORP U S A	NAS 1 19771	189,633
	CNC TURNING AND MILLING MACHINE		
	PHOTONIC MICROSCOPY INC	NAS 3 25529	40,000
	LOW LIGHT LEVEL IMAGING SYSTEM		
	MILDEX INC	NAS 5 29898	77,059
	VERTICAL ROTARY SURFACE GRINDER		
			306,692
EUROPE	BROWN CHARLIE ASSOCIATES CO	NAS 1 18732	125,400
	TELEVISION COLLIMATED DISPLAY SYSTEMS		
	LAMBDA PHYSIK INC	NAS 1 18775	84,030
	EXCIMER LASER SYSTEM		
	GEC AVIONICS LTD	NAS 2 12805	1,456,331
	DEVELOPMENT OF V/STOL RESEARCH AIRPLANE THRUSTLE		
	NOZZLE SERVO & SERVO CONTROL UNIT		
	BIO RAD LABORATORIES	NAS 3 25310	72,250
	SEMICONDUCTOR PROFILE PLOTTER		
	CONNECTICUT TECHNICAL CONSULT	NAS 2 25377	31,930
	COMPUTER CONTROLLED FILM BALANCE (SIC CODE 5086)		
	PERMALI INC	NAS 2 25383	144,970
	WOOD FAN BLADES		
	OXFORD INSTRUMENTS N A INC	NAS 3 25488	52,285
	SUPERCONDUCTING MAGNET SYSTEM		

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1992

COUNTRY	CONTRACTEE	CONTRACT NUMBER	ESTIMATED COST & FEE
DESCRIPTION			
EUROPE	ASTROPHYSICS RESEARCH CORP	NAS 3 37645	30,795
	RADIOGRAPHY SYSTEM		
	ALFITALFA S A I P A	NAS 9 17877	350,000
	TETHERED GRAVITY LABORATORIES STUDY		
	HASSELBROD ENGINEERING AB	NAS 9 17907	40,800
	FILAK MICROMETER MID-HASSELBROD CAMERAS		
	SCHOTT GLASS TECHNOLOGIES INC	NASH 4224	7,663,350
	MANUFACTURE, VERIFICATION AND DELIVERY OF MIRROR BLANKS		
	INSIGHT VISION SYSTEMS INC	NAS10 11473	168,523
	PIGGY BACK CAMERA SYSTEM		
	A R R PHOTONICS INC	NAS10 11535	41,034
	SPARE PARTS NASA-OWNED ROBOT		
			10,166,882
NORTH AMERICA	BOWEN INC	NAS 1 18614	142,600
	OPTICAL FT-IR SPECTROPHOTOMETER		
	I S G TECHNOLOGIES INC	NAS 2 17786	130,965
	GRAPHICS DISPLAY WORKSTATION		
	YORK UNIV	NAS 3 30254	490,137
	HUBBLE SPACE TELESCOPE GUARANTEED TIME OBSERVATION PROGRAM SUPPORT		
	LUMONICS INC	NAS 5 30505	16,245
	REPAIR & RETROFIT OF GSEC RARE GAS HALIDE EXCIMER LASER		

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17th CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1980

COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FEE
	DESCRIPTION		
NORTH AMERICA	CUMMILARGE ELECTRIC SUPPLY HIGH VOLTAGE CABLE	NAS 4 31503	15,672
	CANADIAN COMMERCIAL CORP PULSED AMPLIFIER	NAS 5 31516	155,000
	CANADIAN COMMERCIAL CORP RECOVERY SYSTEMS ASSYS.	NAS 5 31534	500,841
	CANADIAN COMMERCIAL CORP BLACK SPART IX AND X HARDWARE	NAS 5 31565	3,564,949
	LUMONICS INC EXCIMER-PUMPED DYE LASER SYSTEM.	NAS 6 37389	86,140
	LUMONICS INC PULSED CO2 TRANSVERSE EXCITED ATMO SPHERIC LASER	NAS 6 37693	45,000
			5,167,169
TOTAL			15,640,743

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1987

COUNTRY	CONTRACTOR	DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FEE
ASIA	N T N BEARING CORP AMERICA	BALL BEARINGS	NAS 3 22049	6,314
	SUNITE ELECTRIC U.S.A INC	GAAS WAFERS	NAS 3 25164	9,600
				15,914
AUSTRALIA	QANTAS AIRWAYS LTD	INCORP SERVICE BULLETINS/JT40-7AH ENGINE	NAS 6 17848	4,214,404
				4,214,404
EUROPE	PERKAL INC	FABRICATION OF FAN BLADES FOR THE 7X10 WIND TUNNEL	NAS 1 18369	273,756
	SAAB SYSTEMS INC	THREE POSITION MEASUREMENT SYSTEM	NAS 1 18504	170,000
	ZEISS CARL INC	CARL ZEISS ANALYTICAL TRANSMISSION ELECTRON MICROSPY 902 WITH ACCESSORIES	NAS 2 12633	264,645
	WIGGLESWORTH T & MACHINERY	ONE LARGE SPINDLE HORN LATHE	NAS 3 25044	273,162
	RAIZERS CORP	RESIDUAL GAS ANALYZER	NAS 5 24877	38,520

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1997

COUNTRY	CONTRACTOR	DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FEE
EUROPE	ASTROPHYSICS RESEARCH CORP	X-RAY SYSTEM	NAS 4 95598	34,695
	DUITS NEDERLANDSE WIND TUNNEL	WINDTUNNEL SUPPORT & SERVICES	NASW 4146	525,663
				1,510,441
NORTH AMERICA	HERCULES INC	F-104 GEAR LEGS	NAS 2 12665	18,010
	CANADIAN COMMERCIAL CORP	ENGINEERING AND FIELD SUPPORT SERVICES	NAS 5 29793	1,668,567
	CANADIAN COMMERCIAL CORP	BLACK BRANT V ROCKET MOTORS & ASSOCIATED HARDWARE	NAS 5 29793	7,232,184
	CANADIAN COMMERCIAL CORP	DEVELOP IN-SUIT DOPPLER PUFFLE DETECTOR	NAS 9 17397	74,300
				8,993,051
POLYTO RICH	COMPUJYR TECHNOLOGY INC	RESEARCH AND DEVELOPMENT CONTRACT FOR REVERSE ENGINEERING FOR INFORMATION SYSTEMS	NAS 7 980	46,915
				46,918

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1996

COUNTRY	CONTRACTOR	DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FEE
ASIA	SALEM TOOLS INC	NUMERICALLY CONTROLLED, KNEE-TYPE MILLING MACHINE	NAS 1 18319	58,500
				58,500
EUROPE	QUANTEL INC	DIGITAL IMAGE PROCESSING SYSTEM	NAS 2 12304	33,395
	QUANTEL INC	VIDEO IMAGE ENHANCEMENT	NAS 3 24932	44,225
	ATOMIKA INC	ION SOURCE	NAS 3 24944	113,900
	ROTADATA INC	BLADE CLEARANCE MEASUREMENT INSTRUMENTATION	NAS 3 24949	38,468
	V G INSTRUMENTS INC	X-RAY PHOTOELECTRON SPECTROSCOPY SURFACE ANALYSIS SYSTEM	NAS 3 25014	359,000
	ERNST RAUMFABRIKTECHNIK GMBH	SPACELAB SPARES, ASSIGNMENT OF CONTRACT FROM THE EUROPEAN SPACE AGENCY TO NASA	NAS 433600A	10,575,534
	INSTITUTO NACIONAL DE TECNICA	OPERATION AND MAINTENANCE OF MADRID D STATION	NASA 4148	72,000,000
				83,164,522

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COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FEE
	DESCRIPTION		
NORTH AMERICA	CANADIAN COMMERCIAL CORP	NAS 2 12244	7,407,496
	CREW STATION RESEARCH AND DEVELOPMENT FACILITY		
	PERKINS INC	NAS 2 12287	45,000
	MAIN LANDING GEAR LEGS		
	PHOTOCHEMICAL RESEARCH ASSOCS	NAS 3 25005	107,000
	NANO SECOND LASER FLASH SPECTROMETER		
	LUMONICS INC	NAS 5 29399	155,000
	PURE GAS EXCIMER LASER DELIVERY		
	CANADIAN COMMERCIAL CORP	NAS 5 29420	395,102
	BLACK FRONT HARDWARE		
	CANADIAN COMMERCIAL CORP	NAS 5 29679	959,793
	NIHKA ROCKET MOTOR ASSEMBLIES		
	CANADIAN COMMERCIAL CORP	NAS 6 17546	387,190
	FLIGHT RELEASABLE GRAPPLE FIXTURE		
			9,456,581
TOTAL			92,675,603

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1986

COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FEE
	DESCRIPTION		
ASIA	SUMITOMO ELECTRIC U.S.A. INC. INDIUM PHOSPHIDE AND GALLIUM ARSENIDE WAFERS	NAS 3 24705	10,200
			10,200
EUROPE	MICROSCIENCE INC. PROCUREMENT OF A HEMISPHERICAL ELECTRON ENERGY ANALYZER SYSTEM	NAS 3 24513	50,000
	OXFORD INSTRUMENTS N.A. INC. HELIUM 3 REFRIGERATION SYSTEM	NAS 3 24763	33,528
	TORQUETRONICS INC. TORQUEMETERS	NAS 3 24783	112,845
	MICROSCIENCE INC. X-RAY PHOTOELECTRON SPECTROSCOPY (XPS) SYSTEM	NAS 3 24788	57,250
	V.G. INSTRUMENTS INC. SCANNING ACOUSTIC MICROSCOPE	NAS 3 24821	114,940
	LAMBDA PHYSIK INC. PROVIDE FOR A LAMBDA PHYSIK TUNABLE DYE LASER	NAS 3 29011	31,950
	THORN E.M.I. GENCO INC. PHOTOMULTIPLIER TUBES AND DOCUMENTATION	NAS 3 36283	70,200
	ARIFLEX CORP. AMERICA ARIFLEX 16 542 16mm MOTION PICTURE CAM	NAS 9 17387	234,601
	HASSELBLAD VICTOR INC. HASSELBLAD CAMERA EQUIPMENT	NAS 9 17420	60,078

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1995

COUNTRY	CONTRACTOR	DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FFE
EUROPE	TOMKOTOW CORP	FORKLIFTS	NAS 5 17467	11,963
		MUNICIPAL MECHANIC APPLICATION	NASW 3996	30,000
		COMPUTER CODES Q30FLD AND WALLBL		
	ROLLS ROYCE LTD	THRUST REVERSERS - TRUSL 69, TRUSL 85	NASW 4060	170,400
	THORN EMI TECHNOLOGY INC	HIGH DENSITY RECORDERS	NAS10 11158	808,000
				1,885,755
NORTH AMERICA	LITTON SYSTEMS INC	LITTON INERTIAL REFERENCE SYSTEM	NAS 2 12008	119,500
	ACE ELECTRIC SUPPLY CO INC	MEDIUM VOLTAGE SYNCHRONOUS MOTOR STARTER	NAS 3 24478	15,600
	CANADIAN COMMERCIAL CORP	LIGHT SOURCE	NAS 3 24780	172,448
	LUMENICS INC	EXIMER-MULTI-GAS LASER	NAS 3 24784	48,195
	BOMEN INC	PROVIDE FOR SUMMER/FALL FLIGHT OF THE BOMEN CRYOGENIC MICHELSON INTERFEROMETER SPECTROPHOTOMETER HAR	NAS 5 28778	42,044
	CANADIAN COMMERCIAL CORP	PERFORM UPGRADING AND MAINTENANCE FOR THE SATELLITE AIDED SEARCH AND RESCUE PROGRAM LOCAL USER TERM	NAS 5 29135	469,035

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1985

COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FEE
	DESCRIPTION		
NORTH AMERICA	CANADIAN COMMERCIAL CORP	NAS 5 29220	2,979,454
	PERFORMANCE OF UPGRADES AND MAINTENANCE FOR THE SAS SAT LOCAL USER TERMINALS (LUT'S) AND THE SYSTEM F		
	CANADIAN COMMERCIAL CORP	NAS 9 17225	116,000
	SIX DEGREE FREEDOM HANDCONTROLLER		
	CANADIAN COMMERCIAL CORP	NAS 9 17271	185,620
	DIGITIZE GRAPPLE FIXTURES		
	INDUSTRIAL TECH INC	NAS10 11123	177,804
	CABLE COMPOSITE		
			4,325,700
PUERTO RICO	INTEL CORP	NAS 1 15092	64,100
	NETWORK RESOURCE MANAGER AND ASSOCIATED HARDWARE AND SOFTWARE		
	UNIV PUERTO RICO SAN JUAN	NAS 5 28746	117,300
	PROVIDE FOR A INVESTIGATION OF BIOMASS ACCUMULATION IN SECONDARY TROPICAL FOREST IN EARLY SUCCESSION		
			181,400
TOTAL			6,433,055

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1984

COUNTRY	CONTRACTOR	CONTRACT NUMBER	ESTIMATED COST & FEE
	DESCRIPTION		
EUROPE	HUNTINGTON ALLOYS INC INCONEL ALLOY 446-000 BARS	NAS 3 24150	49,225
	A G A CORP PURCHASE OF INFRARED BANDPASS FILTERS	NAS 5 28316	18,400
	THORN E M I GENCOM INC PHOTO MULTIPLIER TUBES AND DOCUMENTATION	NAS 8 26154	60,350
	HASSELBLAD VICTOR INC HASSELBLAD CAMERA PARTS/ACCESSORIES	NAS 9 17123	74,142
	ARRIFLEX CORP AMERICA 16MM MOTION PICTURE CAMERAS/ACCESSORIES	NAS 9 17188	54,424
	ARRIFLEX CORP AMERICA 16MM MOTION PICTURE CAMERAS/ACCESSORIES	NAS 9 17189	319,646
	THORN E M I TECHNOLOGY INC FOUR TAPE RECORDERS & MAINTENANCE	NAS 9 95571	559,216
	SIEMENS CORP PURCHASE OF EIGHT CATHODE LIFE TEST TRIPGDS ASSEMBLIES	NAS 1 3845	80,687
	DELTA ASSOCIATES MARKETING OF NASA EXHIBIT AT THE HANNOVER TRADE FAIR HANNOVER, W GERMANY	NASW 3903	87,842
	COMETIC INDUSTRIALE SPA UPRITER TRANSFERRED FOR VISA	NAS10 10910	1,302,308
	THORN E M I TECHNOLOGY INC MAGNETIC TAPE RECORDER	NAS10 10964	83,710

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1984

COUNTRY	CONTRACTOR	DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FEE
EUROPE	THORN E.M.I. TECHNOLOGY INC	HIGH DENSITY RECORDERS	NAS10 11043	758,400
				3,454,320
NORTH AMERICA	CANADIAN COMMERCIAL CORP	MODEL 053 GAS CIRCULATION	NAS 1 17747	19,600
	CANADIAN COMMERCIAL CORP	PULSED 50 WATT AVERAGE POWER CO2 LASER	NAS 1 17765	36,500
	R. C. A. CORP	PHOTO-TOUCH OSCILLATOR MODULES	NAS 1 17814	30,700
	CANADIAN COMMERCIAL CORP	STUDY TO DEMONSTRATE ELECTROMAGNETIC SWEEP-FREQUENCY SURFACE SOUNDER	NAS 5 27961	29,000
	CANADIAN COMMERCIAL CORP	CESIUM LAMP STUDY	NAS 5 28143	207,570
	CANADIAN COMMERCIAL CORP	PURCHASE OF COLOR FIRE-240 FILM RECORDER WITH ENGINEERING AND SOFTWARE DOCUMENTATION, SPARE PARTS AND	NAS 5 28190	219,307
	CANADIAN COMMERCIAL CORP	BLACK BRANT X RAY TUBES	NAS 5 28269	420,213
	CANADIAN COMMERCIAL CORP	BLACK BRANT X RAY TUBES RECEIVING SYSTEM ASSEMBLIES (CRSA)	NAS 5 28273	265,177
	DEVELCON ELECTRONICS INC	EXPANSION CABINET POWER SUPPLIES	NAS 8 35657	30,944

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NEW CONTRACTS WITH PLACE OF PERFORMANCE OUTSIDE THE U.S.
FISCAL YEAR 1974

COMPANY	CONTRACT DESCRIPTION	CONTRACT NUMBER	ESTIMATED COST & FEE
NORTH AMERICA	CANADIAN COMMERCIAL CORP FMS SIMULATION/QUALIFICATION	NAS 17137	3,870,000
		HARDWARE	
	CANADIAN COMMERCIAL CORP FED FOR FIBER OPTIC SENSE	NAS10 10920	105,616
	DEVELOPEL ELECTRONICS INC PROCUREMENT ASSN	NAS10 11061	3,944,171
			6,143,796
	TOTAL		12,598,116

QUESTION #14: PLEASE PROVIDE THE FOLLOWING INFORMATION WITH REGARD TO SUPPORT CONTRACTORS.

- A. THE NUMBER OF EMPLOYEES OF SUPPORT CONTRACTORS BY CENTER.
B. THE ASSOCIATED EMPLOYEE COST BY CENTER.

ESTIMATED R&PM FUNDED SUPPORT SERVICE CONTRACT WORKYEARS AND COST BY CENTER:

	FY 1989		FY 1990		
	WKYRS	COST	WKYRS	COST	
JOHNSON	1,392	58,847	1,482	68,541	
KENNEDY	1,942	97,185	1,942	108,585	
MARSHALL	582	24,860	595	29,666	
STENNIS	189	9,076	189	9,739	
GODDARD	779	25,459	928	38,211	
AMES	469	22,624	506	27,083	
LANGLEY	462	16,473	499	20,972	
LEWIS	598	30,506	634	33,695	
HEADQUARTERS	890	31,335	890	43,091	
AGENCY TOTAL	7,303	316,365	7,665	379,583	

Question 15a:

Please summarize the results of the latest round of SES bonuses.

Answer 15a:

NASA's results of the latest round of SES bonuses.

<u>Number of</u> <u>Awards</u>		<u>Percent of</u> <u>Salary</u>	<u>Amount</u> <u>Distributed</u>	<u>Percent of</u> <u>SES</u>
7	at	20%	\$108,500	
13	at	15%	150,210	
43	at	10%	323,971	
<u>112</u>	<u>at</u>	<u>5%</u>	<u>416,034</u>	
175			\$998,715	38%

Presidential Rank Awards: 31 recipients \$360,000

Question 15b:

Please summarize the results of the most recent year under "merit pay".

Answer 15b:

NASA is covered by PL 98-615, which established the Performance Management and Recognition System (PMRS) to replace the "merit pay" system. In FY 1988, slightly less than the statutory maximum amount for PMRS performance awards, 1.5 per cent of estimated aggregate PMRS salaries, was paid to PMRS employees. The dollar amount paid was approximately \$2,786,000.

Question 15c:

Please summarize the current listing of re-hired annuitants.

Answer 15c:

NASA currently, as of November 1988, has ten re-employed annuitants serving in full-time appointments and one in a part-time appointment.

<u>Name</u>	<u>Instal.</u>	<u>Grade</u>
Coy, Edward F.	HQS	Admin. Determ.
Driver, Elwood T.	HQS	SES
Kerrigan, Ronald	HQS	GM-13
King, Mary Anne H.	HQS	GS-12 (part-time)
Smith, Eloise W.	HQS	GS-07
Taylor, Charles	HQS	GS-15
Williams, Walter C.	HQS	SES
Evans, James Suddath	GSFC	GM-14
Jackson, James C.	GSFC	GS-15
Jones, Robert E.	KSC	GS-13
Nicholson, James	KSC	GS-14

An additional 61 re-employed annuitants, primarily experts, consultants or advisory committee members are on NASA rolls under intermittent appointments and may serve on a daily basis when requested. These individuals serve without compensation (WOC) or are paid for the days when actually employed (WAE).

WITHOUT COMPENSATION (WOC) EMPLOYEES

<u>Name</u>	<u>Instal.</u>	<u>Grade</u>
Albrecht, Albert P.	HQS	Consultant
Beattie, Donald A.	HQS	Advis. Cmte Mbr
Chapman, Dean R.	HQS	Consultant
Culbertson, Philip E.	HQS	Consultant
Hearth, Donald P.	HQS	Advis. Cmte Mbr
Lee, Chester M.	HQS	Consultant
McLucas, John L.	HQS	Consultant
Mullin, Jerome P.	HQS	Consultant
O'Brien, John E.	HQS	Consultant
Poritzky, Siegbert B.	HQS	Advis. Cmte Mbr
Rediess, Herman A.	HQS	Advis. Cmte Mbr
Schneider, William C.	HQS	Consultant
Szylis, Robert E.	HQS	Consultant
Gilruth, Robert R.	JSC	Consultant

WHEN ACTUALLY EMPLOYED (WAE) EMPLOYEES

<u>Name</u>	<u>Instal.</u>	<u>Grade</u>
Bryant, Frederick B.	HQS	Consultant
Clark, George Q.	HQS	Consultant
Doherty, Vincent P.	HQS	Expert
Donlan, Charles J.	HQS	Consultant
Fanseen, James F.	HQS	Consultant
Gleason, James P.	HQS	Consultant
Himmel, Seymour C.	HQS	Advis. Cmte Mbr
Hosenball, S. Neil	HQS	Consultant
Kilgore, Edwin C.	HQS	Expert
Krueger, Myron W.	HQS	Consultant
Ludwig, George H.	HQS	Advis. Cmte Mbr
Mayer, Gilbert J.	HQS	Expert
Meredith, Leslie	HQS	Expert
Metcalf, Rayburn A.	HQS	Expert
Morrison, James R.	HQS	Consultant
Naugle, John E.	HQS	Consultant
Pilarinos, George	HQS	Expert
Pozinsky, Norman	HQS	Consultant
Rees, Eberhard F.M.	HQS	Expert
Robinson, Lorne M.	HQS	Consultant
Sade, Richard S.	HQS	Consultant
Shapley, Willis H.	HQS	Consultant
Shaw, James R.	HQS	Consultant
Stock, Richard L.	HQS	Consultant
Truszynski, Gerald M.	HQS	Consultant
Houbolt, John C.	LaRC	GS-15
Richards, Leo O.	MSFC	Expert
Parker, Maurice H.	JSC	GS-13
Beck, Elizabeth R.	KSC	GS-12
Bogart, William M.	KSC	GS-12
Cave, Alfred N.	KSC	GS-12
Charder, Bettye M.	KSC	GS-06
Coleman, Estelle G.	KSC	GS-11
Davenport, Jansen R.	KSC	GS-12
Dorn, Ralph E.	KSC	GS-12
Dyke, Ray A.	KSC	GS-13
Gauger, Paul C.	KSC	GS-12
Huddleston, Robert H.	KSC	GS-12
McRoberts, Joseph J.	KSC	GS-12
Nick, D. Faye	KSC	GS-12
O'Connor, Jerry J.	KSC	GS-12
Senstad, Kenneth P.	KSC	GS-12
Taloni, Angelo J.	KSC	GS-12
Taylor, Annie E.	KSC	GS-12
Underwood, William A.	KSC	GS-12
Whitaker, Philip F.	KSC	GS-12
Yost, Ray E.	KSC	GS-12

QUESTION 16: PLEASE TABULATE, BY CENTER, THE RESEARCH AND
PROGRAM MANAGEMENT FUNDS TO BE USED FOR REPAIR AND
MAINTENANCE OF FACILITIES IN FY 1989 AND FY 1990.

	FY 1989	FY 1990
JOHNSON	10,635	12,216
KENNEDY	18,764	21,590
MARSHALL	4,981	7,302
STENNIS	1,968	2,330
GODDARD	7,119	14,833
AMES	7,672	8,957
LANGLEY	4,097	4,292
LEWIS	9,506	10,770
HEADQUARTERS	4,344	11,815
NASA AGENCY	69,686	94,105

FUNDS ARE USED FOR THE REPAIR AND MAINTENANCE OF
FACILITIES AT NASA FIELD CENTERS AND GOVERNMENT-OWNED
FACILITIES, TO INCLUDE THE DAY-TO-DAY MAINTENANCE AND
MORE SUBSTANTIAL REPAIR OF UTILITY SYSTEMS, THE INTERIOR
AND EXTERIOR OF GENERAL PURPOSE (OFFICE) AND TECHNICAL
BUILDINGS AND STRUCTURES AND PAVEMENT AND DRAINAGE SYSTEMS.

Question 17: Please give a breakdown as to the length of time that cases within the Office of the Inspector General have been pending, i.e., 3 months, 6 months, 1 year, 2 or more years.

Answer:

Length of Time OIG Cases Have Been Pending

<u>Months on Hand</u>	<u>Number of Cases</u>
0-3	65
3-6	43
6-12	51
12-24	43
over-24	33

SUBJECT	SOURCE DOCUMENT	DUE DATE	STATUS
FY 1989 COMMITMENTS			
1. NASA Capital Development Plan	P.L. 100-685	By 3/15/89	Report expected by late April
2. Microgravity Research Capability - NAS and NAPA studies	P.L. 100-685	Immediately	Reports completed and transmitted to Hill on April 12, 1989
3. Microgravity Research Capability - NASA report based on NAS and NAPA studies	P.L. 100-685	No later than 5/15/89	Report expected by due date
4. Space Settlements	P.L. 100-685	Biennially after enactment of Act (11/19/90)	Report expected by due date
5. International Space Docking Capability	P.L. 100-685	Within six months after enactment of Act (5/19/89)	Report expected by due date
6. Oklahoma IAC	P.L. 100-685	No date specified	Integration process is occurring while contract negotiations are underway
7. Space Station Operations Costs	H. Rept. 100-650	Prior to preliminary design review (third quarter of 1990)	Report expected by due date
8. Space Station Management and Integration Costs	H. Rept. 100-650	By mid-November 1988	Report expected by first week of May
9. Use of shuttle external tanks	H. Rept. 100-650	Within 90 days of enactment of Act (2/19/89)	Report expected by mid-May
10. Launch Vehicle Research and Development	P.L. 100-657	By April 15, 1989 (Extension of due date approved by Chairman Roe on April 4)	Report to be transmitted for OMB clearance early-May

SUBJECT	SOURCE DOCUMENT	DUE DATE	STATUS
FY 1988 COMMITMENTS			
1. U.S.-Latin American Cooperation	H. Rept. 100-204	Before 6/30/88	Report expected by late April
2. Space Station Plan - Reimbursements	P.L. 100-147	No later than 9/30/88	Report expected by mid-May
3. Space Grant & Fellowship Program	P.L. 100-147	1/1/89; and not later than 2/15 of every odd-numbered year thereafter	Report expected by mid-May

SUBJECT	SOURCE DOCUMENT	DUE DATE	STATUS
		FY 1986 COMMITMENTS	
1. Space Telescope Ops/Maintenance - post-launch report	H. Rept. 99-32	1/15/88	Currently manifested for 12/89

